DRAFT

GUIDELINES FOR THE APPROVAL AND DESIGN OF NATURAL AND CONSTRUCTED TREATMENT WETLANDS FOR WATER QUALITY IMPROVEMENT

Alberta
ENVIRONMENTAL PROTECTION

FEBRUARY 1998

Standards and Guidelines Branch
Environmental Assessment Division
Environmental Service

Pub. No.: **T/397**
ISBN: **0-7785-0017-9**

More information regarding the "Guidelines for the Approval and Design of Natural and Constructed Treatment of Wetlands for Water Quality Improvement", may be obtained by contacting:

Standards & Guidelines Branch
Environmental Assessment Division
Environmental Service
Alberta Environmental Protection
6th Floor, 9820 – 106th Street
Edmonton, Alberta
T5K 2J6
Phone: (403) 427-6102

Primary Contact:
Karu Chinniah
Standards and Guidelines Branch
Alberta Environmental Protection
6th Floor, 9820 – 106th Street
Edmonton, Alberta
T5K 2J6

Foreword and Acknowledgements

Use of wetlands for water quality improvement is increasingly popular. This manual contains guidelines for the evaluation, design and operation of natural and constructed treatment wetlands for water quality improvement. The guidelines are intended to assist both the regulator and the designer. To the regulator, they are a means of specifying certain requirements that are considered critical in the evaluation and the approval of wetlands for water quality improvement. To the designer, they provide useful guidance as to what the regulator expects in terms of the overall design of the facility.

This manual is considered a draft/working document for one year commencing February 1, 1998. During this period, Alberta Environmental Protection will be pleased to receive any comments from users of the document. The final version of the manual will be published in March 1999.

The document was prepared by CH2M Gore & Storrie Limited under contract. We wish to thank CH2M Gore & Storrie Limited for developing a fairly comprehensive report under a very limited budget.

Alberta Environmental Protection also formed an Advisory / Working Group to provide guidance and direction in the development of the document. We acknowledge with gratitude, the following who participated in the process:

Chinniah, Karu - Environmental Assessment Division, Alberta Environmental Protection

Lang, Pat - Environmental Assessment Division, Alberta Environmental Protection

Lungle, Ken - Wildlife Management Division, Alberta Environmental Protection

Rayner, Marilyn - Resource Data Division, Alberta Environmental Protection

Stewart, Gary - Ducks Unlimited

Williams, Larry - Regional Services, Alberta Environmental Protection

Contents

Tables

Figures

1. Introduction

Alberta Environmental Protection (AEP) occasionally receives requests from municipalities and consultants to use natural wetland areas such as marshes, swamps, and sloughs for polishing of treated municipal wastewater. There has also been considerable interest in the use of constructed treatment wetlands for water quality improvement. This manual was prepared to provide standardized guidelines for the approval of candidate treatment wetland sites by the Alberta Environmental Protection Regional Services Engineers and to provide design guidance to agencies and consultants for natural and constructed wetlands for wastewater polishing. A brief description of several potential wetland applications is presented in Appendix A.

This manual is not intended to be a comprehensive document, since it covers such a wide spectrum of information related to treatment wetlands. Several volumes would be needed to fully cover each topic. It is, however, intended to provide to the AEP a means of specifying the requirements that are considered necessary for the treatment or polishing of wastewater in constructed or natural treatment wetlands. The manual also provides municipalities and consultants with an outline of the expectations of the AEP in terms of overall system design and in terms of procedures that must be followed in selecting wetlands for the treatment or polishing of wastewater.

It is important to note that AEP will allow constructed wetlands only with restricted access as part of the wastewater treatment process. Under this scenario, effluent compliance monitoring will be required at the outlet of the wetlands.

To provide the maximum protection for natural wetlands that are under consideration for conversion to treatment wetlands, the hydraulic and nutrient loading to the wetland will be minimized to reduce the potential for negative impacts on the wetland. The wastewater treatment plant discharge to the wetland will be required to consistently meet tertiary or high quality secondary effluent standards before consideration will be given for discharge to a natural wetland. Intensive monitoring and regular reporting will be required to protect the integrity of the wetland.

The wastewater treatment plant effluent that is being considered for discharge to a constructed treatment wetland will be required to consistently meet primary or secondary effluent standards before consideration will be given for construction of the treatment wetland. Intensive monitoring and regular reporting will be required for this type of system as well to protect the integrity of the wetland.

2. Approach

This document will enable the AEP to screen projects that are presented for approval and provide preliminary guidance for the design process. To accomplish this, a step-by-step approach to the evaluation and design process has been prepared. This allows for an evaluation process that will begin with the least-cost stages that are, for the most part, desktop evaluations and move to those stages that are more labour-intensive and require field investigations.

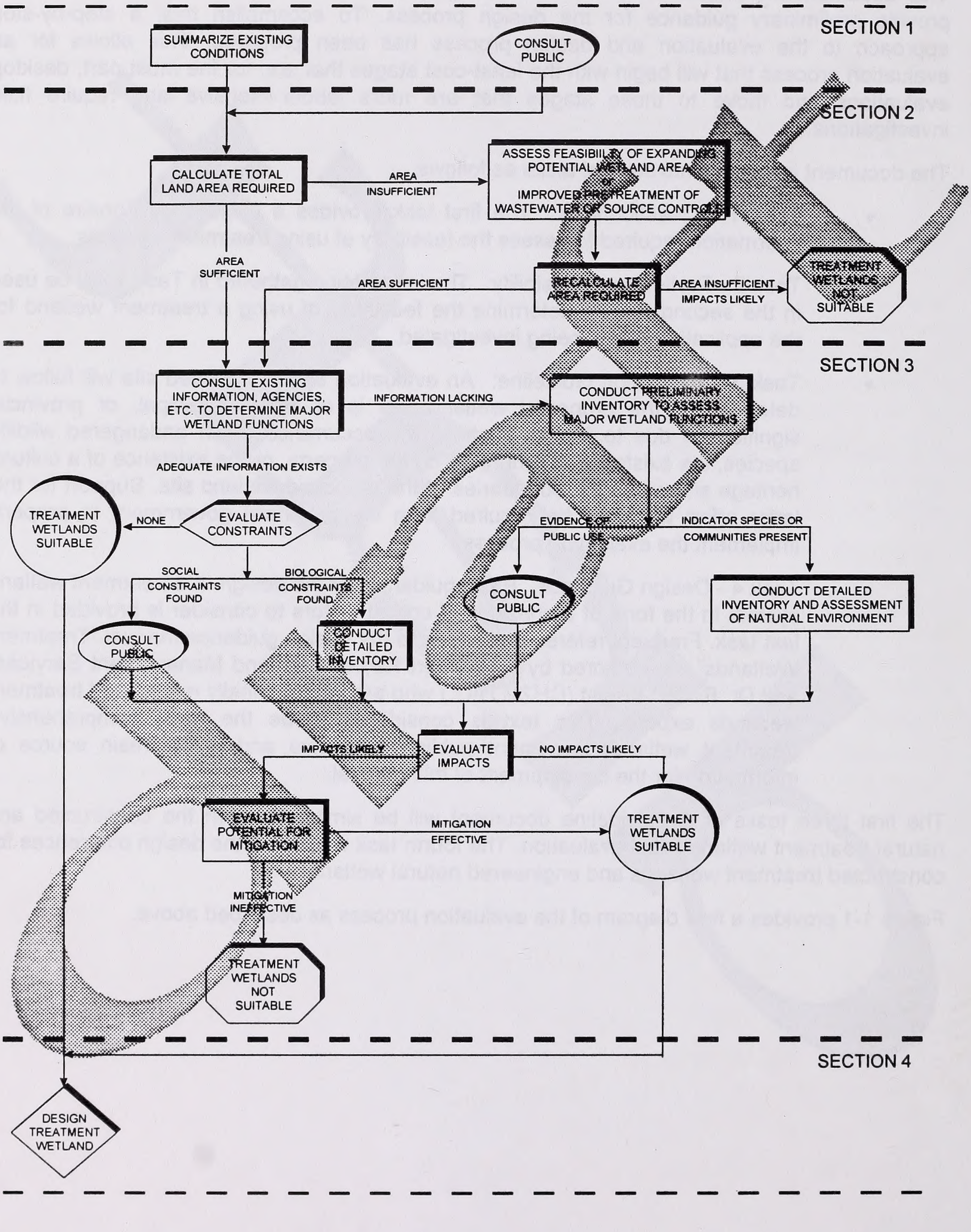
The document is divided into several tasks as follows:

- Task 1 - Questionnaire: The first task provides a basic questionnaire of the information required to assess the feasibility of using treatment wetlands.
- Task 2 - Preliminary Feasibility: The information gathered in Task 1 will be used in the second task to determine the feasibility of using a treatment wetland for the application that is being investigated.
- Task 3 - Evaluation Guideline: An evaluation of the proposed site will follow to determine if the proposed wetland site is of local, municipal, or provincial significance due to factors such as the occurrence of an endangered wildlife species, the existence of a heronry on the property, or the existence of a cultural heritage site within the boundaries of the proposed wetland site. Support for this latter effort will likely be required from the provincial government to properly implement the evaluation process.
- Task 4 - Design Guidance: Basic guidance for the design of a treatment wetland system in the form of a checklist of critical factors to consider is provided in the last task. Frequent reference is made to the design guidance manual "Treatment Wetlands", co-authored by Dr. Robert Kadlec (Wetland Management Services) and Dr. Robert Knight (CH2M HILL) who are internationally recognized treatment wetlands experts. This text is considered to be the most comprehensive treatment wetlands document published to date and is the main source of information for the development of this manual.

The first three tasks of the guideline document will be similar for both the constructed and natural treatment wetland initial evaluation. The fourth task will reflect the design differences for constructed treatment wetlands and engineered natural wetlands.

Figure 1-1 provides a flow diagram of the evaluation process as described above.

FIGURE 1-1
PRELIMINARY WETLAND EVALUATION FLOW CHART FOR APPROVAL OF CONSTRUCTED WETLANDS FOR WATER QUALITY IMPROVEMENT



3. Questionnaire

The questionnaire presented in Table 3.1 documents the basic information required to determine the feasibility of using a treatment wetland for polishing of a wide variety of industrial, agricultural, and municipal wastewater discharges. Included is site location, type of wastewater pretreatment, pretreated water quality, hydraulic loading, soil conditions, land availability, effluent water quality objectives (must the discharge criteria be met at the point of inflow to the wetland or at the point of outflow?), current land use, topography, and climatic factors. If a natural wetland is considered for treatment purposes, additional information that may be required includes the type of wetland, dominant vegetation, existing stormwater and/or wastewater input sources, soil conditions (soils map), and feasibility of constructing an inflow and/or an outflow structure if required.

Upon completion of the questionnaire, the collected data must be reviewed, and contaminant loadings determined and compared to provincial guidelines. Further investigation will be warranted if a particular contaminant is determined to be of concern. Further treatment of the wastewater may be required prior to inflow to the wetland system either in the existing wastewater treatment plant or as a separate treatment unit.

It must also be determined if portions of the treatment wetland system will be accessible to the public. This will have some bearing on the type of treatment wetland that will be most suited to the treated wastewater source. Control of public access will be required where exposure to partially treated wastewater may result in illness. Typically, risk of exposure is minimized toward the outflow end of the system and will likely be suitable for public enjoyment for hiking and wildlife viewing.

The types of wetlands that are best suited for the applications in Alberta are presented in the next task.

Table 3.1 - Description of Candidate Wastewater Treatment Wetland - Alberta

Potential Wetland Location Site Data

Site Name: ______________________________

City/Community: ______________________ Population: __________

Wastewater Source: (describe)
- Municipal: ______________________
- Industrial: ______________________
- Other: ______________________

Other Anticipated Wetland Uses: nature study ___ hunting ___ aquaculture ___ other __________

Key/sensitive wildlife habitat: ______________________

Wastewater Pretreatment: ______________________

Stormwater:
- Watershed Area: __________ Units: __________
- Runoff Coefficient: __________

Design Flow: __________ Units: __________

Site Substrate Material (eg. sand, clay, muck, sandy clay, clayey sand, etc): __________

Permeability: ______________________

% Vegetation Cover: submergent ___ emergent ___ meadow ___ forest ___

Land Area Available: __________ Units: __________

Proximity to Water/Wastewater Source: ______________________

Current Site Land Use:	______	Zoning: ______	Ownership: ______
Adjacent Land Use (north):	______	Zoning: ______	Ownership: ______
Adjacent Land Use (east):	______	Zoning: ______	Ownership: ______
Adjacent Land Use (south):	______	Zoning: ______	Ownership: ______
Adjacent Land Use (west):	______	Zoning: ______	Ownership: ______

Presence of:
- Existing or Potential Limiting Land Use (eg. Environmentally Sensitive Area) ___
- Protected Species ___ Historical or Archaeological Resources On or Near Site ___
- Aquifers ___ Aquitards ___ Natural Wetlands ___

% of Available Land Area Covered by Natural Wetlands: _____

Type of Natural Wetland:
- Marsh ___ Open Water ___ Floating Aquatic ___
- Shrub ___ Forest ___ Unknown ___
- Other ___ (Describe) __________

Dominant Plant Species: ______________________

Existing Discharges to the Natural Wetland (describe): __________

Site Topography: ______________________

Is the wetland landlocked? Yes___ No ___

If no, what water body will/does the treatment wetland discharge to? __________

Water body classification:

Wetland outlet location and description: __________

Define watershed border: __________ Area:__________ ha

Upland buffer zone description: __________ Width:__________ m

Comments:

____

____

____

____

Table 3.1 (Continued) - Description of Candidate Wastewater Treatment Wetland - Alberta

Monitoring - Average Data - Potential Discharge to the Treatment Wetland
Wastewater Treatment Plant Effluent/Stormwater Discharge

Operating Season (months): ____________

Period of Record : Start (Year) ________ End (Year) ________

Years in Service: ________

Average Flow (m^3/day): ________

Parameter	Concentration	Units	Loading	Units
BOD_5		mg/L		kg/d
TSS		mg/L		kg/d
TDS		mg/L		kg/d
Turbidity			- -	
NH_4-N		mg/L		kg/d
NO_3-N+NO_2-N		mg/L		kg/d
Total Nitrogen		mg/L		kg/d
TKN		mg/L		kg/d
Organic Nitrogen		mg/L		kg/d
Total P		mg/L		kg/d
Filtered P		mg/L		kg/d
Dissolved Oxygen		mg/L		kg/d
Redox Potential			- -	
Sulfate/Sulfide		mg/L		kg/d
Conductivity			- -	
Alkalinity		mg/L		kg/d
pH			- -	
Temperature		°C	- -	
Chloride		mg/L		kg/d
Metals (list)				
Pesticides/Herbicides (list)				
Organics (list)				
Fecal Coliform		col/100ml	- -	
E.coli		col/100ml	- -	

Additional Contaminants Not Listed:

Table 3.1 (Continued) - Description of Candidate Wastewater Treatment Wetland - Alberta

Monitoring - Average Data - Existing Natural Wetland Outflow

Period of Record : Start (Year) ________ End (Year) ________

Average Flow (m^3/day): ________

Parameter	Concentration	Units	Loading	Units
BOD_5		mg/L		kg/d
TSS		mg/L		kg/d
TDS		mg/L		kg/d
Turbidity			- -	
NH_4-N		mg/L		kg/d
NO_3-N+NO_2-N		mg/L		kg/d
Total Nitrogen		mg/L		kg/d
TKN		mg/L		kg/d
Organic Nitrogen		mg/L		kg/d
Total P		mg/L		kg/d
Filtered P		mg/L		kg/d
Dissolved Oxygen		mg/L		kg/d
Redox Potential			- -	
Sulfate/Sulfide		mg/L		kg/d
Conductivity			- -	
Alkalinity		mg/L		kg/d
pH			- -	
Temperature		°C	- -	
Chloride		mg/L		kg/d
Metals (list)				
Pesticides/Herbicides (list)				
Organics (list)				
Fecal Coliform		col/100ml	- -	
E.coli		col/100ml	- -	

Additional Contaminants Not Listed:

Table 3.1 (continued) - Description of Candidate Wastewater Treatment Wetland - Alberta

Treatment Wetland System Outflow Targets

Discharge criteria to be met at wetland inflow ___ or wetland outflow ___

Dissolved Oxygen (mg/L): ____________

pH: ____________

BOD_5 (mg/L): ____________

TSS (mg/L): ____________

NH_4-N (mg/L): ____________

Total Nitrogen (mg/L): ____________

TP (mg/L): ____________

Fecal Coliform (col/100 mL) ____________

Approved Flow (per day, week, month, year) ____________

Approval Duration: __annual __seasonal __monthly __other (describe)

Treatment Wetland Contact Details

Last Name: ____________

First Name: ____________

Role: Operator __ Eng.Design/Study __ Research & Development __ Performance Monitoring __

Organization: ____________

Address: ____________

____

Phone#: ____________

Fax#: ____________

Climatic Factors

Avg # of Frost-free Days	____________	
Avg Annual Temperature	____________	Units: ____
Avg Winter Temperature	____________	Units: ____
Annual Snowfall	____________	Units: ____
Annual Rainfall	____________	Units: ____
Annual Precipitation	____________	Units: ____
Elevation		Units:

Comments:

____

4. Preliminary Feasibility of Treatment Wetlands for Wastewater Polishing

In this task, a portion of the information that was gathered in the first task will be processed. The wetland area requirement will be determined and areal and contaminant loading rates will be compared with reported values from other treatment wetland systems. At this point, it will likely be determined whether the land area available will provide adequate treatment to meet the effluent objectives. If the total land area required is not available, options for reducing the wetland footprint required, such as determining the effects of enhanced pretreatment on the wetland area requirement, are presented. A copy of a typical spreadsheet for determining the wetland area required for wastewater polishing is presented in Table 4.1 for a surface flow (SF) system and Table 4.2 for a subsurface flow (SSF) system. Appendix B contains sample completed spread sheets.

It will be necessary to determine whether a SF or SSF treatment wetland, or a combination of the two, is the best option for the application. Factors to be considered include land area availability, funding, and potential for physical contact by area residents with the treatment process.

Three types of treatment wetland systems that can be considered for wastewater polishing in Alberta include:

- Natural wetlands
- Surface flow constructed wetlands
- Subsurface flow constructed wetlands

Each of these alternatives briefly is described below.

Natural Wetlands

Natural wetlands have been used for the treatment and disposal of secondary wastewater effluent for many years. There are many existing discharges to natural wetlands nationwide. While most of these systems were not designed for wastewater and stormwater treatment, studies of some natural wetlands have led to an understanding of the natural ability of wetland ecosystems for pollutant assimilation and to the design of new natural water treatment systems.

The proper use of a natural wetlands system for the treatment of secondary wastewater or stormwater involves a number of considerations. Research indicates that matching hydraulic loads to the hydroperiod requirements and tolerances of the dominant wetlands vegetation species reduces the potential for vegetation changes. At high organic and nutrient loadings, some natural wetlands may be significantly degraded. Plant species are likely to shift to herbaceous marsh species such as cattails (*Typha* spp.). Optimal treatment occurs when the pretreated water is well-distributed throughout the wetland and travels through as sheet flow. Ideally, alternative discharge areas or "treatment cells" are used to reduce the hydraulic and nutrient loadings that might otherwise affect the vegetation community in the treatment cells.

Table 4.1 - Alberta Environmental Protection - Wetlands Guidelines

Surface Flow (SF) Treatment Wetland - Preliminary Feasibility Calculation Sheet

Instructions: Fill in the single outline boxes with data gathered in Section 1, then calculate the values for the double outlined boxes.

Location: ______________________________

Design Flow, m^3/d — **Q=** [ ]

		TSS	BOD	TP	TN	NH_4-N	Org-N	FC
Influent Concentration	C_i =	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Target Effluent Concentration	C_e =	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
Wetland background limit, mg/L for TSS, $C^* = 7.8 + 0.063C_i$ for BOD, $C^* = 3.5+0.053C_i$	C^* =	[ ]	[ ]	0.05	2	0	1.5	100
Areal rate constant @ 20°C, m/yr.	k =	1000	34	12	22	18	17	77
Required wetland area, ha	A =	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

$$A = \left(\frac{0.0365 \times Q}{k}\right) \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

maximum calculated area from above boxes (A_{max}) = [ ] ha

		TSS	BOD	TP	TN	NH_4-N	Org-N	FC
Effluent concentration, mg/L via k-C* model	C_o @ maximum area =	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

$$C_o = C^* + (C_i - C^*)\exp\left(-\frac{kA_{max}}{0.0365 \times Q}\right)$$

Table 4.2 - Alberta Environmental Protection - Wetlands Guidelines

Subsurface Flow (SSF) Treatment Wetland - Preliminary Feasibility Calculation Sheet

Instructions: Fill in the single outline boxes with data gathered in Section 1, then calculate the values for the double outlined boxes.

Location: ______________________________

Design Flow, m^3/d **Q=** [ ]

		TSS	BOD	TP	TN	NH_4-N	Org-N	FC
Influent Concentration	C_i =							
Target Effluent Concentration	C_e =							
Wetland background limit, mg/L for TSS, $C^* = 7.8 + 0.063C_i$ for BOD, $C^* = 3.5 + 0.053C_i$	C^* =			0.05	2	0	1.5	100
Areal rate constant @ 20°C, m/yr.	k =	1000	34	12	22	18	17	77
Required wetland area, ha	A =							

$$A = \left(\frac{0.0365 \times Q}{k}\right) \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

maximum calculated area from above boxes (A_{max}) = [ ] ha

		TSS	BOD	TP	TN	NH_4-N	Org-N	FC
Effluent concentration, mg/L via k-C* model	C_o @ maximum area =							

$$C_o = C^* + (C_i - C^*)\exp\left(-\frac{kA_{max}}{0.0365 \times Q}\right)$$

Definitive studies of the performance of natural wetlands for water quality enhancement have been completed. These studies demonstrate that, through careful design, some natural wetlands can consistently and cost-effectively provide advanced treatment of wastewater and stormwater constituents.

Surface Flow (SF) Constructed Wetlands

Constructed wetlands usually are shallow, man-made impoundments planted with emergent, rooted vegetation. These wetlands may be planted manually or naturally colonized by "volunteer" plant communities. Some constructed wetlands contain monocultures of cattails (Typha spp.) or bulrushes (Scirpus spp.), while others are planted with more diverse plant communities that have greater stability under changing seasonal and water quality conditions.

Unlike a natural wetlands system in which hydrology is largely fixed by the tolerance limits of the existing plant community, a constructed wetland can be designed to regulate water depth and residence time, two of the most important factors in wetlands treatment design. Also, the design of constructed wetland systems can feature parallel cells or cells in series. Such a system can be operated to rotate discharge points or to use slightly different treatment capabilities of the various available plant species groups. SF constructed wetlands have relatively low construction, operation, and maintenance costs compared with conventional advanced treatment technologies.

The emergent plants of SF wetlands are not harvested to remove nutrients. Instead, the natural assimilative capacity of the microbial flora (bacteria and fungi) that attach to the plants provides efficient and reliable removal of biodegradable organics and nitrogen (ammonia and nitrate). Metals and phosphorus can be sequestered in plant materials and wetland sediments. Because much of the treatment that occurs in wetlands is from microbial, physical, and chemical action rather than plant uptake, these systems continue to function during winter. The processes that rely on microbial action, such as nitrogen removal, continue but at a slower rate. The processes that rely on physical and chemical action will continue unaffected by the change in water temperature below the ice surface. If the treated wastewater continues to flow through the winter months, the snow and ice cover can provide an effective temperature buffer that will allow continued treatment.

Subsurface Flow (SSF) Constructed Wetlands

SSF wetlands are gravel- or soil-based wetlands in which the wastewater passes through the porous substrate rather than above an impermeable substrate. The large surface area of the media and the plant roots provides ample sites for microbial activity. SSF systems use many of the same emergent plant species as SF systems. When treating an equivalent volume of flow, gravel-based SSF wetlands use less acreage than SF constructed wetlands.

SSF wetland systems have an advantage in cooler climates because so much of the treatment occurs below the ground surface. These systems are therefore less affected by cold air temperatures. Also, gravel-based systems may be relatively low in maintenance requirements and are less likely to have odour and mosquito problems than are lagoons. When properly designed, gravel-based wetland systems have high efficiency rates for removing biodegradable organic matter and nitrate-nitrogen from wastewater.

A consideration that makes the SSF system attractive, especially for small communities and individual residences, is the reduced potential for human contact with partially treated sewage and the related health implications. This is an important consideration especially when there is public access to a treatment facility for wildlife viewing or other related outdoor activities. The use of an SSF system as a pretreatment step followed by an SF system is an option to consider.

Major disadvantages of SSF constructed wetland systems include their tendency for plugging and overall system costs, which can be five times more than an SF system for a certain pollutant mass removal.

Table 4.3 summarizes the North American treatment wetland operational performance for systems receiving municipal and industrial wastewater and stormwater. It is important to note that the summary table represents data collected from existing systems and does not reflect design target loadings.

TABLE 4.3
SUMMARY OF NORTH AMERICAN TREATMENT WETLAND OPERATIONAL PERFORMANCE FOR SYSTEMS RECEIVING MUNICIPAL AND INDUSTRIAL WASTEWATER AND STORMWATER (KADLEC AND KNIGHT, 1996)

Parameter	Wetland Type	Average Concentration (mg/L)			Average Mass (kg/ha/d)		
		In	Out	Eff (%)	Loading	Removal	Eff (%)
BOD5	SF	30.3	8.0	74	7.2	5.1	71
	SSF	27.5	8.6	69	29.2	18.4	63
TSS	SF	45.6	13.5	70	10.4	7	68
	SSF	48.2	10.3	79	48.1	35.3	74
NH_4-N	SF	4.88	2.23	54	.93	.35	38
	SSF	5.98	4.51	25	7.02	.62	9
NO_2+NO_3-N	SF	5.56	2.15	61	.8	.4	51
	SSF	4.4	1.35	69	3.1	1.89	61
ORG-N	SF	3.45	1.85	46	.9	.51	56
	SSF	10.11	4.03	60	7.28	4.05	56
TKN	SF	7.6	4.31	43	2.2	1.03	47
	SSF	14.21	7.16	50	9.3	3.25	35
TN	SF	9.03	4.27	53	1.94	1.06	55
	SSF	18.92	8.41	56	13.19	5.85	44
O-P	SF	1.75	1.11	37	.29	.12	41
	SSF	ND	ND	ND	ND	ND	ND
TP	SF	3.78	1.62	57	.5	0.17	34
	SSF	4.41	2.97	32	5.14	1.14	22
Bacteria	SF			2 log reduction			
	SSF			2 log reduction			

BOD_5 = 5-day Biochemical Oxygen Demand
TSS = Total Suspended Solids
NH_4-N = Ammonia Nitrogen
NO_2+NO_3-N = Nitrite + Nitrate Nitrogen
ORG-N = Organic Nitrogen
TKN = Total Kjeldahl Nitrogen
TN = Total Nitrogen
O-P = Ortho Phosphorous
TP = Total Phosphorous
ND = No Data
SF = Surface Flow
SSF = Subsurface Flow

Average livestock treatment wetland concentration performance data for selected parameters is presented in Table 4.4. This data was prepared as part of a report that summarized livestock

treatment wetlands performance in Canada and the U.S. It was noted during the preparation of the livestock treatment wetlands performance document that the nutrient and solids loading to many of the systems in the database was far in excess of the loadings to the municipal and industrial systems as reported in Table 4.3. Also, many systems were under-designed and therefore produced a relatively poor quality effluent when compared to typical Environment Ministry discharge criteria. However, the overall impact of installing the treatment wetland was the reduction of the contaminant loading to the receiving water. The construction of such a system, even if somewhat undersized, provides sufficient treatment to merit consideration.

TABLE 4.4
AVERAGE LIVESTOCK TREATMENT WETLAND PERFORMANCE FOR REMOVAL OF BOD_5, TSS, NH_4-N, AND TN
(KNIGHT, PAYNE, PRIES, BORER, CLARKE, 1997)

Wastewater Type	Average Inflow Concentration (mg/L)	Average Outflow Concentration (mg/L)	Average Concentration Reduction (%)
BOD_5			
Cattle Feeding	113	22	80
Dairy	404	129	68
Poultry	153	115	25
Swine	81	33	59
TSS			
Cattle Feeding	291	55	81
Dairy	914	432	53
Swine	107	49	54
NH_4-N			
Cattle Feeding	5.1	2.2	57
Dairy	74.3	30	59.6
Poultry	74	59.2	20
Swine	203.6	110.6	46
TN			
Dairy	129.2	47.7	63
Poultry	89	69.7	22
Swine	373.3	210.8	44

5. Guidelines for Functions to be Evaluated for Approval of Candidate Site for Treatment Wetland

Wetlands in Alberta serve functions which benefit the ecosystem and, directly and indirectly, humans (e.g. D.A. Westworth and Associates Ltd., 1993, Usher and Scarth, 1990, Alberta Water Resources Commission 1993a, 1993b). Natural wetlands to be considered as candidate sites may already serve several important functions, which could be impaired even by water which has undergone primary or secondary treatment, because of the influx of nutrients, because of the general increase in water levels resulting from wastewater flows, and because certain areas of the wetland may have to be deepened or otherwise altered in order to increase treatment efficiency.

Table 5.1 lists the issues or functions which should be examined when investigating the possibility of using a natural wetland or other natural area for wastewater treatment and is the final summary sheet to be used to summarize all functions examined during investigation of the candidate site. Functions summarized in this table are those which have been found to be important in maintaining biodiversity, particularly in settled landscapes where habitat diversity tends to be gradually eroded and biodiversity declines. Checksheets following Table 5.1 should be used to guide inventories, which are designed to reveal indicators of biodiversity, and assist in determining whether use of the candidate site for wastewater treatment would impair existing functions. Appendixes C to I provide information and references to aid in determining whether indicators found are significant.

The checksheets which make up the bulk of this section summarize a work program to be followed in order to determine whether the candidate site serves functions significant at the provincial level. The candidate site may also serve functions important at a regional level; for example, the presence of a regionally significant species can indicate an unusual habitat or landform in a region which increases regional biodiversity. Significant species and habitats may vary considerably with region. Regional significance of features found in investigations should also be examined as part of candidate site evaluations.

TABLE 5.1
SUMMARY SHEET FOR EVALUATION OF ECOLOGICAL FUNCTIONS OF A CANDIDATE SITE (CHECK APPROPRIATE BOXES AFTER COMPLETING EVALUATION)

Habitat Functions	Desktop Evaluation Significant Features Noted		Field Assessment Significant Features Noted		Negative Impacts Likely?		Mitigation Likely to be Successful?		Basis for Denial Noted	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
5.1: Flood storage capability										
5.2: Water quality improvement										
5.3: Habitat for rare plants or plant communities										
5.4: Significant habitat for breeding waterfowl										
5.5: Significant habitat for migrating waterfowl or shorebirds										
5.6: Habitat for breeding area- and disturbance-sensitive fauna										
5.7: Corridor for floral or faunal distribution										
5.8: Fisheries habitat										
5.9: Habitat for significant animal species										
5.10: Social or economic benefit										

Alberta Department of Environmental Protection Treatment Wetland Evaluation

5.1: Function: Flood Storage Capability

Rationale: Wetlands function in flood and erosion control, water storage, and protection of groundwater recharge and discharge.

Methods for Evaluation

Office evaluation-document the following

Conduct preliminary calculation to determine the area of the watershed draining into the wetland.

Calculate wetland area (if wetland mapping is digitized, this may be done with the same software; otherwise a polar planimeter may be used).

Calculate catchment area.

Calculate average monthly rainfall (Reference Environment Canada 1982 (Appendix C).

Multiply average monthly rainfall by catchment area (minus the area of the wetland).

Multiply by an appropriate runoff coefficient.

Add this figure to figure for effluent volume: assume the wetland is an average of 1m deep.

Is this wetland large enough to hold both natural and effluent inputs?
If wastewater inputs total 10% or more of natural inputs, conduct modelling studies to determine flooding probabilities more accurately. Note ratio of wastewater to natural inputs, and recommend further studies if needed.

Determine probability of flooding during a 1 in 50 year event

(mitigation may be required if probability is high)

Compare flooding with and without effluent:

❑ Wastewater will not increase magnitude or frequency of flooding. Impact on flood control function is not a basis for denial of treatment wetland.

❑ Wastewater will increase magnitude or frequency of flooding. Proceed to evaluation of mitigation.

If Impacts Predicted, Examine Potential for Mitigation

Can a control structure be erected? Yes ❑ No ❑
Describe:

Can storage capacity for water be increased (i.e. by underground or above ground storage structures)?
Note: reconsider possibilities of impacts on other wetland functions as a result of increasing storage.
Describe:

Final Analysis: Predicted Net Impacts and Action

Mitigation Potential:

Conclusions:

❑No negative impact likely. Impact on flood control is not a basis for denial of treatment wetland.

❑Negative impact likely. Impact on flood control is a basis for denial of treatment wetland.

Alberta Department of Environmental Protection Treatment Wetland Evaluation

5.2: Function: Water Quality Improvement

Rationale: Wetlands function to store and transform certain chemical elements which could otherwise affect downstream surface or groundwater quality. Additional inputs from effluent may result in unacceptable water quality downstream.
Increases in water flow can affect this function by reducing the hydraulic retention time in the wetland, (thereby reducing treatment time), and by keeping sediment suspended or resuspending settled material.

Groundwater can become contaminated by recharge from contaminated surficial water table.

Methods for Evaluation (note water quality measurements are part of the initial assessment).

Measure water quality entering and leaving wetland (as reported in preliminary assessment of wetland, Table 1 Section 1). Note where measurements taken (map if necessary).

*Note: in wetlands where inflow or outflow is dispersed, measurements should be taken at several points.
List the following water quality parameters :

Phosphorus:	Inflow_____	Outflow______
Nitrogen:	Inflow_____	Outflow______
Suspended solids:	Inflow_____	Outflow______

List other potential contaminating inputs (ie. feedlot operations, storm water runoff, industries; note both point and non-point sources of contamination).

____

____

____

Recommend other water quality parameters which should be measured based on potential for contamination from surrounding area.

____

____

1. Assess whether this wetland already plays a significant role in improving surface water quality from surrounding inputs.

Explain:

____

____

❑ Wetland does not receive significant inputs. Negative impacts on this function are not a basis for denial of treatment wetland.

❑ Wetland significantly treats water from incoming sources. Proceed to evaluation of impacts.

If wetland currently provides significant water quality improvement, determine potential for impact (based on Section 2 calculation).

Predict impacts from increase in hydroperiod:

____

____

____

Predict impacts from increased nutrient loading:

____

2. Assess potential for contamination of the groundwater table through recharge of surface water

Determine soil type from existing soils data or obtain soil core from the wetland:

Estimate:

Soil permeability____________________

Water balance of wetland____________________

Note whether contaminated water could reach the local aquifer through recharge:

- ☐ No negative impact likely. Impact on water quality is not a basis for denial of treatment wetland.
- ☐ Negative impact likely. Proceed to evaluation of mitigation.

If potential impact is determined, examine potential for mitigation of impacts. Refer to table of Impacts and Mitigation (Appendix D).

Further pretreatment of incoming wastewater:

Pretreatment of wastewater from other sources, or source controls:

Increase the size of treatment wetland (note that potential for impacts to other habitat functions must be re-evaluated):

Final Analysis: Suggested Net Impacts and Action

Conclusions:

- ☐ No negative impact likely. Impact on water quality is not a basis for denial of treatment wetland.
- ☐ Negative impact likely. Impact on water quality is a basis for denial of treatment wetland.

Alberta Department of Environmental Protection Treatment Wetland Evaluation

5.3: Function: Provision of Habitat for Rare Plants or Plant Communities

Rationale: Some plant communities, for example, native prairie, have been almost eliminated by development for agriculture, etc. Rare plants and plant communities are often highly sensitive to changes in nutrient and moisture regimes.

*Note: In some areas where soil disturbance and a high proportion of "weeds" is the norm, predominantly native plant assemblages can be considered significant.

Methods for Evaluation

Office Evaluation

Contact and document correspondence with agencies re. rare species mapping for area (e.g. Department of Environmental Protection, Natural Resources Service; University of Alberta; Alberta Museum of Natural History).

Contact and document correspondence with local sources (Naturalist Clubs, FAN, botany groups, local landowners).

Refer to examples of significant landscape types and localities in Appendix F. Note whether site falls into categories listed as potentially significant.
Refer to Packer and Bradley (1984) (Appendix C) for comprehensive list of rare plants and dot maps of distribution.

- ☐ Sufficient survey data exist, i.e. botanical inventory of site. No significant plant species, community found (see Appendix E for rare plant species). Site is not in an area or landscape noted for potential significance (Appendix F). Presence of significant plant species is not a basis for denial of treatment wetland.
- ☐ Sufficient survey data do not exist. Proceed to preliminary field evaluation.

Preliminary field evaluation must be conducted if no inventory exists, or if the site falls into area or landscape categories noted for their potentially significant vegetation (see Appendix F).

Preliminary Field Evaluation (to be conducted by a qualified vegetation specialist)

Summarize from field notes habitat conditions at the site which may indicate presence of significant plants or plant communities.

Summarize from field notes indicators of significant plants or plant communities at the site (e.g. certain plant species, soils or landform coupled with absence of disturbance by tilling or intensive grazing; history of fire); or presence of significant plant species in similar habitat nearby).

If such indicators are found, particularly if the site is in an area or landscape type noted for potentially significant flora (Appendix F), conduct intensive field evaluation and give rationale for conducting full inventory.

Intensive Field Evaluation

Botanical Inventory (conducted on at least two visits: approximately coinciding with summer and fall. Woodlands should be additionally evaluated in spring).

From field notes, list significant species or plant communities found. Note ratio of native plant species to total species. Append plant community mapping, plant list.

If indicator detected, determine potential for impact: refer to table of impacts and mitigation found in Appendix D.

1 Summarize features which likely contribute to the presence of significant species or communities.

2 Determine zone where impacts may be expected, and:

A. Assess expected impacts from increase in hydroperiod (e.g. potential replacement of extant plant communities by communities more tolerant of inundation).

B. Assess expected impacts from increased nutrient loading (e.g. potential invasion by fast-growing non-native species, change in vegetation, change in water quality, decrease in species diversity).

C. Assess expected impacts from earthworks, if proposed.

- [ ] No impact likely. Impact on significant plant species or communities is not a basis for denial of treatment wetland.
- [ ] Impact likely. Proceed to examination of mitigation.

If potential impact determined, examine the potential for mitigation afforded by the following techniques

Restoration of habitat (e.g. planting of native species, etc.):

Further treatment of wastewater:

Pretreatment of wastewater from other sources, or source controls:

Final Analysis: Suggested Net Impacts and Action

Mitigation Potential:

Summary of Projected Net Impacts After Mitigation. Qualify Projections.

Conclusions: are net impacts acceptable? Explain:

- [ ] No negative impact likely. Impact on significant plant species or communities is not a basis for denial of treatment wetland.
- [ ] Negative impact likely. Impact on significant plant species or communities is a basis for denial of treatment wetland.

Alberta Environmental Protection Treatment Wetland Evaluation

5.4: Function: Significant Habitat for Breeding Waterfowl

Rationale: Even small wetlands have been shown to be important in waterfowl production, particularly in prairie and parkland ecoregions. Initiatives like the North American Wetland Management Program (NAWMP) recommend protection of potholes.

Methods for Evaluation

Office Evaluation:

Contact Ducks Unlimited; Department of Environmental Protection Natural Resource Service for pre-existing information re: breeding waterfowl. Note whether site is subject to NAWMP agreement.

Refer to the following references (Appendix C): Strong et al. (1993) for information on value of wetlands in the Settled Area to waterfowl, Nietfield et al. (1985) for list of priority duck production habitat in Alberta, and Refer to D.A. Westworth & Associates (1990) for significant breeding habitat in Boreal Forest region

Document known level of significance:

____

____

____

Contact local sources (Naturalist clubs, FAN, Alberta Fish and Game Association). List or append sources including name, phone number of contact and significance of habitat.

Document level of significance from these sources:

____

____

- ☐ Wetland is not considered significant and has been evaluated within past 5 years. Significant habitat for breeding waterfowl is not a basis for denial of treatment wetland. If information not available, conduct preliminary field visit.
- ☐ Wetland is considered significant. Proceed to evaluate potential for impact.

If information is not available, conduct preliminary field visit to determine potential significance.

Preliminary field visit:

Note following variables:

- ☐ 50m (diameter) or more standing water until late summer
- ☐ Concealing vegetation
- ☐ Discrete areas of short, grass-like plants
- ☐ Submerged or floating aquatic vegetation
- ☐ Shrubby areas
- ☐ Check if other wetlands with standing water (as above) are within 5 km; linked by natural habitat; linked by agricultural land, i.e. not separated by ecological barrier

If standing water plus three or more of these conditions apply, a field evaluation must be conducted: note whether field evaluation advised.

Yes ☐ No ☐

- ☐ Wetland is not considered significant, and preliminary field visit does not indicate potential significance. Habitat for breeding waterfowl is not a basis for denial of treatment wetland.
- ☐ Wetland is considered significant. Habitat for breeding waterfowl is a basis for denial of treatment wetland.

Intensive field evaluation (to be conducted by a qualified waterfowl biologist)

Conduct and provide record of one of the following waterfowl surveys:

Conduct observational and nest (dragging) surveys in late April to June.

Conduct surveys of downy young and post-breeding adults in May-July.

Estimate number and species of waterfowl pairs observed

Assess significance of habitat

As estimated from field surveys:____________________

In consultation with agencies noted above :

____

____

- ❑ Wetland is not considered significant. Breeding habitat for waterfowl is not a basis for denial of treatment wetland.
- ❑ Wetland is considered significant. Determine and record the potential for impact.

Determination of Potential for Impact

1. **Assess factors contributing to significance of habitat based on:**
   - Factors noted above
   - High percentage of wetlands in the region
   - Large and undisturbed habitat tract
   - Other
2. **Determine zone where impacts may be expected, and**

   A Predict impacts from increase in hydroperiod (also note potential for positive impact from increase in permanence of water, area of wetland, etc.). Refer to table of impacts in Appendix D.

   ____

   ____

   B Predict impacts from increased nutrient loading.

   ____

   ____

   C Assess expected impacts from earthworks, if proposed:

   ____

If potential negative impact expected, examine potential for mitigation:

Refer to table of impacts and mitigation techniques in Appendix D and habitat matrix (Appendix G) to aid in determining impacts due to vegetation shifts.

Potential for mitigation offered by creating habitat.

____

____

____

Potential for mitigation offered by further pretreatment of wastewater.

____

____

Assess potential for success of mitigation:

Summary of net impacts after mitigation:

Final Analysis: Suggested Net Impacts and Action

- ❑ No negative impact likely. Impact on waterfowl breeding habitat is not a basis for denial of treatment wetland.
- ❑ Negative impact likely. Impact on waterfowl breeding habitat is a basis for denial of treatment wetland.

Conclusions:

Alberta Department of Environmental Protection Treatment Wetland Evaluation

5.5: Function: Significant Habitat for Migrating Waterfowl or Shorebirds

Rationale: Migrating shorebird and waterfowl populations are vulnerable to human interference, since they concentrate in great numbers in only a few locations along migratory pathways (Dickson and Smith 1991).

Methods for Evaluation

*Note: Field evaluation of significance of habitat for migrating waterfowl and shorebirds is sufficiently complex to be beyond the scope of this evaluation. Evaluation of this criterion will be general and based on existing information only.

Office Evaluation:

Contact agencies re. Mapping of significant staging areas (e.g. Department of Environmental Protection Natural Resources Service, Canadian Wildlife Service, Ducks Unlimited). Tabulate below agency, contact person, phone number and date of call.

Note published reports listing significant staging areas (eg. Dickson and Smith 1991, Nietfield et al. 1985, Poston *et al*. 1990; Appendix C).

* Dickson and Smith (1991) note that Regional Shorebird Staging Reserves are those which have at least 20,000 using the site annually or at least 5% of a species flyway population.

____

____

____

- ❑ No significant shorebird or waterfowl staging area noted. Presence of staging area is not a basis for denial of treatment wetland.
- ❑ Significant migratory staging area noted. Proceed to examination of impacts and mitigation.

If staging area noted, determine potential for impact:

Refer to table of impacts and mitigation techniques, Appendix D.

1. Summarize features which contribute to significance as a staging area:
   - ❑ Extensive open water and concealing vegetation.
     Comments:____________________
   - ❑ Presence of large areas of mud flat or short grass-like vegetation.
     Comments:____________________
   - ❑ Other:____________________;
     Comments:____________________
2. Determine zone of influence where impacts can be expected, and:

   A. Predict impacts from increase in hydroperiod (e.g. particularly inundation of mud flats, or extension of inundation time with consequent failure of forage species to germinate and/or loss of invertebrates).

   ____

   ____

   ____

   B. Predict impacts from increased nutrient loading (e.g. rapid growth of suboptimal non-native forage species, elimination of some invertebrates).

   ____

   ____

C. Predict impacts from earthworks, if proposed: ______

- ❑ No negative impact likely. Impact on significant staging area is not a basis for denial of treatment wetland.
- ❑ Negative impact likely. Proceed to evaluation of mitigation.

If potential impact determined, examine potential mitigation of impacts

1. Restoration of habitat (e.g. creation of gentler grades (1:10) at wetland edges to encourage zonation of vegetation and development of mud flats).
2. Further pretreatment of wastewater

Final Analysis: Suggested Net Impacts and Mitigation

Mitigation Potential

Summary of net impacts after mitigation

Conclusions

- ❑ No negative impact likely. Impact on significant staging areas is not a basis for denial of treatment wetland.
- ❑ Negative impact likely. Impact on significant staging areas is a basis for denial of treatment wetland.

Alberta Department of Environmental Protection Treatment Wetland Evaluation

5.6: Function: Habitat for Breeding Area - and Disturbance-Sensitive Fauna (see list of species in Appendix G).

**Note: This part of the evaluation should be completed only in developed or agricultural areas where habitat is highly fragmented.*

Rationale: Some wildlife species appear to require large expanses of habitat (or many connected patches of habitat) at a distance from human development. These species are becoming increasingly rare in settled landscapes.

Office Evaluation

Contact agencies re. species lists for area (e.g. Alberta Department of Environmental Protection Natural Resource Service). List sensitive species recorded (noted in Appendix G). Also note species recorded in contiguous or structurally similar habitat within 1 km.

____

____

____

Contact local sources (naturalist clubs, FAN, birding groups) for species lists in area or in contiguous or structurally similar habitat within 1 km. Summarize findings.

____

____

____

- ☐ Sufficient data exist; no significant fauna found. Or no data available, but habitat consists of small (< 5 ha), isolated patches of natural vegetation in a landscape which consists of <10% of natural habitat.
  Presence of area-, disturbance- or isolation-sensitive species is not a basis for denial of treatment wetland.
- ☐ Insufficient Data exist (i.e. no surveys within past 4 years): conduct field evaluation

Field Evaluation (to be conducted under the following circumstances):

- If large areas (>5 ha) of grassland, woodland or wetland persist in an otherwise highly developed landscape).
- If candidate site is one of many fragments of habitat which together comprise greater than 10% of natural vegetation in the landscape.

*Note: In many cases, the requirement for inventories to detect rare species will provide the opportunity for concurrent surveys for these species.
Note habitat conditions which indicate the possible presence of area- or disturbance- sensitive species (e.g. above factors).

____

____

Conduct breeding bird, amphibian and reptile, and mammal species as indicated for rare species function. Note area- or disturbance-sensitive indicator species found (refer to list in Appendix G): summarize findings.

____

____

____

- ☐ Sensitive species not found. Presence of sensitive species is not a basis for denial of treatment wetland.
- ☐ Sensitive species found. Proceed to evaluation of impacts.

If indicator detected, determine potential for impact (refer to Appendix D for summary of impacts and Appendix G for habitat matrixes which aid in determination of affects of shifts in vegetation):

1. Summarize features which likely contribute to the presence of sensitive species.
   - Large and undisturbed habitat tract:__________
   - High percentage of habitat cover in the region:__________
   - Other:__________

2. Determine zone where impacts may be expected, and:

   A. Predict impacts from increase in hydroperiod (e.g. replacement of treed habitat by more water-tolerant species; see Appendix D for summary of impacts):

   B. Predict impacts from increased nutrient loading (e.g. change in vegetation, change in water quality, decrease in plant species diversity):

   C. Predict impacts from earthworks, if proposed:

- ☐ No negative impact likely. Impact on area-, disturbance- or isolation- sensitive species is not a basis for denial of treatment wetland.
- ☐ Negative impact likely. Proceed to examination of mitigation.

If potential impact determined, examine potential mitigation of impacts; e.g. by creation of corridors to other suitable habitat, restoration of habitat outside area affected by creation of wetland to maintain habitat size, etc.).

Final Analysis: Suggested Net Impacts and Action

Mitigation Potential:

Summary of Net Impacts after Mitigation:

Conclusions:

- ☐ No negative impact likely. Impact on area- , disturbance- or isolation-sensitive species is not a basis for denial of treatment wetland.
- ☐ Negative impact likely. Impact on area-, disturbance- or isolation-sensitive species is a basis for denial of treatment wetland:

Alberta Department of Environmental Protection Treatment Wetland Evaluation

5.7: Function: Provision of Significant Habitat for Floral or Faunal Distribution and Persistence Within the Landscape

Rationale: Wetlands and other natural areas being considered as candidate sites may be linked to other patches of habitat. Without the pattern of nodes and linkages, habitat becomes fragmented and generally supports lower biodiversity.

Methods for Evaluation

Office Evaluation

Obtain up-to-date aerial photographs of the site and approximately 1 km radius beyond the site. Note discrete patches of vegetation (nodes) and patterns of natural vegetation connecting them (linkages).

____

Note and record whether candidate site forms a node or part of a linkage.

____

Note and record whether linkage takes the form of a potential "stepping stone" rather than a direct connection.

____

Note predominant land use surrounding nodes and linkages.

____

Contact agencies (as suggested for other functions) to determine whether large animal populations are known to use the site or surrounding habitat as a corridor. List species reported.

____

❑ No linkage is evident. Impact on node or linkage function is not a basis for denial of treatment wetland.
❑ Linkage is evident; or large animal populations use the area as a corridor. Proceed to evaluation of impacts.

If candidate site forms part of a node or a linkage, evaluate potential for impacts:

1. Summarize main features contributing to significance of nodes or linkages e.g.

   Linkages provide the only natural corridor through otherwise intensively farmed agricultural land or urban development: Yes ❑ No ❑
   Comment:

   ____

   ____

   ____

   Site contributes to natural landscape significant for size, configuration, links: Yes ❑ No ❑
   Comment:

   ____

   ____

   ____

2. Evaluate zone of influence, and:

   A. Predict impacts from increase in hydroperiod:

   ____

   ____

   ____

B. Predict impacts from increased nutrient loading:

C. Assess expected impacts from earthworks, if proposed:

- ❑ No negative impact likely. Impact on node or linkage is not a basis for denial of treatment wetland.
- ❑ Negative impact likely. Proceed to evaluation of potential for mitigation.

If potential impact determined, examine potential mitigation of impacts and summarize:

Restoration of habitat (e.g. restoration of corridor elsewhere, restoration of node edges in order to improve configuration, size):

Mitigation Potential:

Final Analysis: Suggested Net Impacts and Action

Summary of Net Impacts after Mitigation:

Conclusions:

- ❑ No negative impact likely. Impact on significant node or linkage is not a basis for denial of treatment wetland.
- ❑ Negative impact likely. Impact on significant node or linkage is a basis for denial of treatment wetland.

Alberta Department of Environmental Protection Treatment Wetland Evaluation

5.8: Function: Provision of Habitat for Fish

Rationale: Though treatment wetlands will not be permitted to affect major fish habitats such as lakes, rivers and streams, pools in some wetlands can provide habitat for some small fish species. Proposals to alter fish habitat are subject to the federal Fisheries Act.

Methods for Evaluation

Office Evaluation

Contact agencies such as the Alberta Department of Environmental Protection Natural Resources Service for existing survey data on the candidate site and hydrologically connected water bodies. List survey data, note significant findings (Refer to list of significant fish species in Appendix H).

Contact local fishermen (through angling groups, etc.). List name, phone number, address and date of contact. Note findings.

Refer to D. A. Westworth and Associates (1990) for lists of significant fish habitat in the boreal forest region.

- ❑ Suitable information exists. Fish habitat is not found on the site, nor is the site hydrologically connected to larger water bodies. The presence of fish habitat is not a basis for denial of treatment wetland.
- ❑ Information is not available. Proceed to field evaluation.

Field Evaluation (to be conducted by a qualified fisheries biologist)

Sample fish populations in potential habitat on site (this is most effectively done with an electroshocker). List numbers and species of fish seen.

Determine if the candidate site contains the following habitat variables:

1. Surface water connection with larger water body containing fish.
2. Areas of emergent vegetation adjacent to larger water body subject to flooding in spring.

- ❑ Fish are present in the wetland, or habitat variables apply. Proceed to evaluation of impacts.
- ❑ Fish are not present, or habitat isolated from larger water bodies containing fish. Negative impact on fish habitat is not a basis for denial of treatment wetland.

Evaluation of Impacts

Refer to table of impacts and mitigation, Appendix D, and habitat matrix to aid in determination of impacts due to vegetation shifts, Appendix G).

1 Assess factors contributing to presence of fish in water bodies on candidate site (noting whether the population in these water bodies is likely killed off in some years and some seasons but maintained by colonization by fish from adjacent habitat).

2 Determine zone where impacts may be expected and:

A. Predict impact of increased nutrient levels (i.e. note tolerance to changes in water chemistry of fish species present: also consider tolerance of prey items):

B. Predict impact of increased hydroperiod (i.e. potential introduction of predatory species, increased flow rates through habitat):

C. Predict impacts of earthworks, if proposed:

❑ Potential impact predicted. Proceed to examination of mitigation.

❑ No negative impact likely. Impact on fisheries habitat is not a basis for denial of treatment wetland.

If potential impact determined, examine potential mitigation of impacts:

Restoration of habitat i.e. creation of sheltered pools, protective structures, fish barriers:

Further pretreatment of incoming wastewater:

Final analysis: suggested net impacts and action

Mitigation potential:

Summary of net impacts after mitigation:

Conclusions:

- ❑ No negative impact likely. Impact on fish habitat is not a basis for denial of treatment wetland.
- ❑ Negative impact likely. Impact on fish habitat is a basis for denial of treatment wetland.

Alberta Department of Environmental Protection Treatment Wetland Evaluation

5.9: Function: Habitat for Significant Animal Species

Rationale: Wetlands provide breeding and foraging habitat for a large proportion of the province's significant species; particularly in grassland regions.

Methods for Evaluation

Office Evaluation

- Contact agencies re rare species mapping for area (e.g. Department of Environmental Protection, Natural Resource Service; Provincial Museum of Alberta). List significant species recorded. Refer to lists of significant animal species, Appendix H.

- Contact local sources (local naturalist clubs, FAN, birding groups). List sources including name, phone number of contact, and significant species sighted. Refer to lists of significant animal species, Appendix H.

- ❑ Sufficient data exists (surveys within the past 5 years), and no significant animal species found. Presence of significant species is not a basis for denial of treatment wetland.
- ❑ Insufficient data exist. Proceed to field evaluation.

Field Evaluation (scoped to reflect effort required as determined by questions answered in the office) to be conducted by a qualified wildlife biologist.

Refer to provincially significant, bird, mammal, reptile, and amphibian species (Appendix H for lists).

- List habitat conditions which may indicate rare species. Refer to habitat matrices, Appendix G and habitat notes in Appendix H.

- Conduct breeding bird surveys (generally from last week in May to first week in July, but certain groups may be better inventoried earlier, e.g. raptors, waterfowl - conspicuous displays in late April). Many species can be detected by song and call identification, so there is a high return in detecting a large diversity of species with least effort. List significant findings from field notes. Append complete species list.

- Conduct scoped breeding amphibian and reptile surveys (surveys of frogs in late evening through April to July bring high return because frogs can be discerned by call; surveys of amphibian eggs or larvae are time-consuming and require uncommon expertise; generally searches under debris can be conducted during other surveys, but bring low return for effort). List significant species from field notes. Append complete species list.

  ____

  ____

  ____

- Conduct mammal surveys if likelihood of rare mammals is high: techniques include searches for mammal signs (generally reveals only a few common species); - mammal trapping (to be used only if strong indications rare mammals may be present and their determination is critical, as return for effort is low, expertise required high and mortality of trapped animals high). List significant species from field notes. Append complete species list.

  ____

  ____

  ____

- ☐ No significant species detected. Significant animal species is not a basis for denial of treatment wetland.
- ☐ Significant species detected. Proceed to evaluation of impacts.

If indicator detected, determine potential for impact:

1. **Summarize features which probably contribute to presence of significant species** (see habitat matrices, Appendix G; habitat notes, Appendix H):
   - large and undisturbed habitat tract: ________________________
   - specific vegetation type: ________________________
   - other: ________________________
2. **Assess zone where impacts can be expected, and:**

   A. Predict impacts from increase in hydroperiod (e.g. replacement of treed habitat by more water-tolerant species; see Appendix D for summary of impacts and mitigation, Appendix G (habitat matrix) to aid in determining impacts due to vegetation shifts).

   ____

   ____

   ____

B. Predict impacts from increased nutrient loading (e.g. potential invasion by fast-growing exotic species, change in vegetation, change in water quality, decrease is species diversity).

C. Predict impact from earthworks, if proposed.

- ☐ No negative impact likely. Impact on significant animal species is not a basis for denial of treatment wetland.
- ☐ Negative impact likely. Proceed to examination of mitigation.

If potential impact determined, examine potential mitigation of impacts.

Restoration of habitat (e.g. peripheral planting, creation of nesting, foraging, or wintering habitat structures):

Further pretreatment of incoming wastewater:

Final Analysis: Suggested Net Impacts and Action

Mitigation Potential:

Summary of Net Impacts After Mitigation:

Conclusions:

____

____

____

- ☐ No negative impact likely. Impact on significant animal species is not a basis for denial of treatment wetland.
- ☐ Negative impact likely. Impact on significant animal species is a basis for denial of treatment wetland.

Alberta Department of Environmental Protection Treatment wetland evaluation

5.10: Function: Provision of Significant Human Economic or Social Benefits

Rationale: Humans derive social and economic benefits from natural areas such as passive and active recreation, derivation of marketable goods and agricultural use.

Methods for Evaluation

Office Evaluation

Contact the following potential users to determine passive recreational use: schools, naturalist clubs, trail clubs, etc. List sources including names, phone numbers.

Contact agencies and non-governmental organizations such as Department of Environmental Protection (Natural Resource Service), Ducks Unlimited, Alberta Fish and Game Association to determine active recreational use; document as above.

Contact agencies, NGO's and local band councils re. Value of activities such as trapping, fishing, peat extraction, wild rice harvest, livestock use, haying, forestry.

- ❑ No information available: conduct preliminary field visit.
- ❑ Contacts inform that site is not used for human purposes. Negative impact on social and economic benefits is not a basis for denial of treatment wetland.

Preliminary Field Visit

Note the following in the field:

- ❑ Presence of hiking, bicycle, snowmobile paths
- ❑ Shotgun shells
- ❑ Signage
- ❑ Wild Rice (harvest to be determined from contact with above sources)
- ❑ Signs of peat extraction
- ❑ Grazing, trampling by livestock; haying
- ❑ Forestry

- ❑ Human use is detectable. Proceed to public consultation or evaluation of potential mitigation.
- ❑ No human use is detectable. Proceed to public consultation (Option 1).

Option 1: Preliminary (optional) public consultation

If the site is used to treat sewage, it will become inaccessible to the public.
Conduct preliminary Public Information Centre or distribute information to inform potential users of benefits and impacts of using site for constructed wetland. Obtain public comment. Append summarized responses.
*Note: The most important impact of using the site for a treatment wetland is that it will no longer be accessible for public use: evaluation of other impacts is not necessary.

- ☐ Public concerns not resolved. Proceed to evaluation of potential mitigation
- ☐ Public concerns resolved. Negative impact on social and/or economic benefits is not a basis for denial of treatment wetland

Option 2: Proceed directly to evaluation of potential mitigation.

Mitigation of Potential Impacts

Refer to table of impacts and mitigation, Appendix D.

1. Determine zone where impacts can be expected, and:

   Assess potential for relocation of passive recreation elsewhere:

   ____
   ____
   ____

   Assess potential for relocation of active recreation elsewhere:

   ____
   ____
   ____

   Assess potential for relocation of consumptive activities elsewhere:

   ____
   ____
   ____

2. Mandatory public consultation: Present benefits of proposed treatment wetland, projected impacts and proposed mitigation at Public Information Centre.

   Summarize public comment, append responses:

   ____
   ____
   ____

   Hold subsequent meetings to resolve individual concerns

   Summarize comments and responses:

   ____
   ____
   ____

- ☐ Public concerns can be resolved. Negative impacts on human social and economic benefits is not a basis for denial of treatment wetland.
- ☐ Public concerns cannot be resolved because negative impacts on social and economic benefits of site are likely. Negative impacts on human social and economic benefits of site is a basis for denial of treatment wetland

6. Design

Upon completion of the first three stages, if indications are that the chosen site is appropriate for use as a treatment wetland, then the preliminary design will begin. The requirements for the constructed and the natural treatment wetlands begin to diverge at this point. Each is presented in the following sections.

It is important to note that at the design stage, it is critical to have available access to recently published treatment wetlands design documents as well as experienced and competent treatment wetlands designers who are up-to-date on the most recent design changes. The level of success of the treatment wetland will be dependent on these factors. This evaluation document does not provide the level of information required to complete a detailed treatment wetland design. However, a listing of the critical components that must be considered is provided and appropriate design documents are referenced. A summary of wetland design guidelines is presented in Appendix J.

Constructed Treatment Wetlands Design

It is anticipated that the constructed treatment wetland will be designed primarily for treatment purposes. The typical relatively high nutrient loadings to these systems, when compared to natural wetlands, provides conditions that tend to favour a mono-culture of high nutrient-tolerant emergent plant species such as cattail.

The design guidance provided in the guidelines is of a general nature only. References for and approaches to design are found in Appendix J and provide an outline of the level of design guidance required to carry the project to a final design stage.

One alternative approach is to provide a workshop to present an overview on the treatment wetland's function and design principles followed by a design workshop. Arrangements for this approach can be made by calling CG&S.

Natural Treatment Wetlands Design

The design of a natural treatment wetland requires an additional evaluation to determine whether the existing wetland is to remain relatively unchanged or if reduction in the diversity of flora and fauna will have a severe negative impact on the wildlife community or generate public opposition. The natural wetlands may be well suited to being divided into a series of wetland cells. The cells closest to the wastewater source will receive the highest loading and maintain the lowest plant diversity whereas the wetland cells further downstream will be able to maintain a greater plant and wildlife diversity. The design guidance provided in Appendix J is of a general nature with reference to treatment wetlands documents for details. These documents are referenced at the end of Appendix J.

Treatment Wetlands: Design Considerations

General considerations for the design of a treatment wetland are summarized below. It is important to note that these are intended to provide the wetland designer with a very basic

overview of a typical treatment wetland design. However, each system is site-specific and the assistance of an experienced treatment wetland designer or careful review of a treatment wetland design manual such as 'Treatment Wetlands' (Kadlec and Knight, 1996) is critical to the success of a treatment wetland project.

General design considerations are as follows:

- Design and implement with designated objectives constantly and clearly in mind
- Pretreatment of the wastewater, to at least primary and preferably to secondary quality with emphasis on suspended solids removal
- Soils should be suited to support wetland vegetation
- Vegetation can be cost effectively transplanted from local donor sites including ditches maintained by the Department of Highways and construction sites where small pocket wetlands are to be removed
- Freezing conditions during the winter months will not adversely affect the wetland community (plants, microbes) but treatment efficiency of parameters that rely on bacterial action for concentration reduction will be reduced
- Design more for function than for form. A number of forms can probably meet the objectives, and the form to which the system evolves may not be the planned one.
- Design relative to the natural reference system(s), and do not over-engineer.
- Design with the landscape, not against it. Take advantage of natural topography, drainage patterns, etc.
- Design the wetland as an ecotone. Incorporate as much "edge" as possible, and design in conjunction with a buffer and the surrounding land and aquatic systems.
- Design to protect the wetland from any potential high flows and sediment loads
- Plan on enough time for the system to develop before it must satisfy the objectives. Attempts to short-circuit ecological processes by over-management will probably fail.
- Design for self-sustainability and to minimize maintenance

Considerations for the size and configuration of the wetland are:

- Active treatment depth is 0.1 to 0.6 m with an average permanent wetland water depth at 0.3 m. 1 m deep zones to be excavated perpendicular to the flow for flow redistribution and for fish and submerged or floating aquatic vegetation habitat
- Minimum hydraulic retention time for a SF wetland is 7 to 10 days, for SSF wetland 2 to 4 days, and for a natural wetland 14 to 20 days
- Average hydraulic loading should be approximately 3 cm/d or 3.3 ha/1,000 m^3/day

- Length to width ratios can be as low as 1:1. Lower length to width ratios result in lower construction costs.
- Shape and location of the treatment cell(s) can vary and depends on landscaping features required for attracting wildlife and for public enjoyment, and relief of available land.

Flow regime and control recommendations are as follows:

- Gravity flow is the preferred method of movement of water into, through, and out of the treatment wetland
- Bottom slope of less than 0.1% is recommended and a flat side-to-side bottom to promote sheet flow through the system
- Vertical flow is discouraged and a liner will be required for soils with less than 10^{-6} permeability
- Incorporate a bypass that will collect first flush flows in the wetland and divert high flows during extreme rainfall events around the wetland if high inflow/ infiltration is evident in the existing sanitary sewer
- Adjustable inflow and outflow structures are required to regulate flow into and out of the system and to regulate the water depth
- Winter operation under freezing conditions during the winter months may require raising of the water level to allow for the space requirement for the ice cover

Ancillary benefits that increase the value of the wetland are:

- Landscaped features can provide an attractive park-like setting
- Wildlife habitat, wildlife viewing opportunities, hiking areas, educational opportunities, and restoration of lost wetland areas that can be incorporated into the wetland design

Nuisance controls that should be considered are:

- Mosquito control includes providing habitat for baitfish (fathead minnows), dragon flies, purple martins, swallows, and bats
- Odour control is not required since the treatment wetlands, if designed properly, do not generate odours
- Nuisance wildlife including carp and muskrat will require control since they will destroy or consume the wetland vegetation and will, in the case of the carp, re-suspend settled materials

Treatment Wetlands Operation

The Canadian experience to date has been that most treatment wetlands in northern climates receive stored wastewater from a lagoon on a seasonal basis for optimum contaminant removal efficiency. Wetland systems can be operated through the winter months but must be over

designed to compensate for the reduced contaminant removal rates during cold weather operation, particularly for nitrogen concentration reduction.

Continuous dischargers must concern themselves at the design stage with providing sufficient insulation to keep the treatment wetland from freezing. This has been accomplished by designing enough freeboard in the system to allow the water level to be raised in the fall, allowing the surface to freeze, and lowering the water level. The dead vegetation stalks will act as support structures for the ice sheet. The snow/ice/air gap can provide sufficient insulation to allow continuous flow through the winter months, especially if the wastewater discharge is sufficiently warm. The construction of a SSF system will also reduce or eliminate the potential of the wastewater freezing. Layers of snow, ice, dead plant materials, and the air gap in the top 0.1 to 0.2 m of the gravel bed will provide an insulating barrier to the cold. To maintain continuous discharge and meet discharge criteria, it will also be important to design the system with a hydraulic retention time sufficient to reduce the nitrogen and organic contaminant concentrations under cold water temperature conditions. This will require additional land area as compared to a seasonal system that would operate under warmer water temperature conditions.

In climates similar to that of many parts of Alberta, year-round treatment wetland systems have been installed and have demonstrated high removal efficiencies. In areas where risk of freezing the system due to low or no flow will not allow for year-round discharge, a storage lagoon will be required. Based on the Canadian Climate Normals published by Environment Canada, the monthly average temperatures indicate that, for a seasonal discharge system, treated wastewater can be discharged to the wetland from approximately April to October since average ambient air temperatures are above freezing. The actual discharge season will depend on depth of ice cover in the wetland, thawing of inflow and outflow structures, and water temperature above approximately 5°C. For high nitrogen removal efficiencies under cold weather condition, the hydraulic loading rate must be reduced at low water temperatures if the wetland has been designed for warm water operation.

Capital, Operation, and Maintenance Costs

Wetland construction costs are determined by the cumulative cost of land, earthwork, planting, design, monitoring and maintenance. Surface flow constructed wetlands in the United States typically cost between $10,000 and $50,000 per hectare, depending upon system size (Kadlec and Knight, 1996). Wetland construction costs that fell outside this range included those where a liner was required, special attention was given to the removal and subsequent replacement of the topsoil, economy of scale was lost due to the small size of the installation, and/or special architectural features were incorporated into the wetland design so that it would be a more attractive feature for the surrounding community. The high cost of gravel fill can raise the price per hectare of subsurface flow wetlands to as much as about four times the cost of surface flow wetlands. However, subsurface flow wetlands can handle greater contaminant loading rates than surface flow wetlands reducing the land requirements.

Operation and maintenance costs depend upon the extent of monitoring data collection, exotic plant control, burrowing animal activity into the berms (animal control, berm repair), and water management.

Public Participation

It is critical to maintain open communication with the communities adjacent to the chosen treatment wetland site. There is considerable misinformation and a lack of understanding of the benefits of treatment wetlands that could lead to strong opposition to this option for wastewater polishing. A public meeting with qualified environmental and treatment wetlands experts will provide a forum where questions about the natural treatment approach can be addressed. Questions and concerns that have been raised over the years include issues such as:

- What about mosquitoes?
- Do we know enough about this relatively young technology to be confident in our design of the system?
- Will it continue to function in the winter?
- Will wetlands treat all contaminants and be applicable to all wastewater streams?
- Are there any large scale applications?
- Will storm events wash out accumulated contaminants?
- Will metals and toxic compounds accumulate in the soil and sediment and adversely affect the wildlife that is attracted to it?

Prior consideration of these questions will assist in the public consultation process. Responses to these questions and others are found in Appendix K.

APPENDIX A
WETLAND APPLICATIONS

A. Wetland Applications

The intent of this publication is to provide municipal planners and the farming community with enough information to consider wetlands treatment as a wastewater treatment alternative. However, there is a potential for applying this technology to a wider spectrum of wastewater and stormwater sources. Federal and provincial lands could benefit considerably from this technology since it offers a low cost alternative to more conventional forms of wastewater and stormwater treatment. A brief description of several of these potential uses is listed below.

Municipal Wastewater Treatment

Successful treatment of primary and secondary effluent from both activated sludge and lagoon systems, landfill leachate and septic tank effluent using wetlands is well documented. Typically, these systems are applied to small communities where land is readily available at a reasonable cost. Many of the Canadian applications that have been constructed in the colder climates have been designed for seasonal discharge or to meet the regulatory guidelines prior to discharge to the wetlands and are providing tertiary treatment to the wastewater stream.

Farm Feedlot/Agricultural Runoff

Approximately 20 projects are underway across Canada where constructed wetlands are being used to curb the runoff from farm feedlots into open ditches that eventually flows into nearby water courses or percolates into the ground affecting the groundwater quality. The cost associated with constructing a wetland has been estimated to be as little as one tenth of that of building a liquid manure tank. Many of these systems are designed for zero discharge, relying on evaporation and irrigation for the disposal of the water. Providing a buffer edge that allows stream, river and pond banks to naturally vegetate and preventing cattle from grazing in and around the water edge provides treatment for field and feedlot runoff.

The use of treatment wetlands ties in very closely with municipal wastewater treatment where the farming community and villages, towns, and cities share a common watershed. The regulating authorities in Ontario, for example, consider nutrient 'swapping' as an alternative to upgrading a municipal wastewater treatment plant. The municipality provides source controls for selected portions of the farming community equal to or greater than the anticipated loading increase by the wastewater treatment plant. A treatment wetland is one of many source controls that are available to the farming community.

National/Provincial Parks

Campsites within national and provincial parks could benefit from the wetland technology from several standpoints. Since most parks operate on a seasonal basis, the design of these systems would not require that they be built to meet winter operation criteria and could easily be modified in the future if year-round operation was desired. Wetlands could be incorporated into the environmental education program although care would have to be

taken to reduce the risk of campers coming into contact with the wastewater and the pathogens it may contain. Wetlands may be of particular interest to campsites located in the northern areas of Canada.

First Nation Lands

Native settlements are often in remote locations and are frequently poorly served by acceptable wastewater treatment facilities. Wetlands offer an opportunity for a wastewater and stormwater treatment alternative that will blend into the natural environment. Construction and management of these systems would provide an employment opportunity for the local residents as well as full control over every aspect of the wetland treatment project. Providing wildlife habitat would be seen as another attractive benefit to a wetland system.

Northern Communities

Currently, many northern communities are using facultative storage lagoons for their wastewater treatment needs. Most have permits to discharge the lagoon contents during the summer months. A growing number of communities in the Yukon, Northwest Territories, northern BC, and northern Alberta are incorporating wetlands into the wastewater treatment to provide a better quality effluent and, in some cases, to extend the discharge period.

Stormwater Treatment Wetlands

Stormwater wetlands are constructed wetlands that improve water quality, modify flow rates by storing water temporarily in shallow pools that create growing conditions suitable for emergent and riparian wetland plants, attenuate flow and reduce downstream scouring and erosion (MOEE,1992 and Shueler, 1992). Shueler describes five basic stormwater wetland designs: shallow marsh, pond/wetland, extended detention, pocket wetlands, and fringe wetlands. All are essentially surface flow systems, with varying emergent marsh and deep pool habitat, and hydraulic capacity, residence time, and travel routes.

In recent years, interest has shifted from providing stormwater attenuation with retention ponds alone, to incorporating vegetated wetland cells into the design to provide greater attenuation and contaminant removal. The accompanying database indicates those communities with installed wetlands as part of their stormwater management system and several that are awaiting approval from the regulating authorities or are in the predesign or design phase.

Sludge Drying/Biosolids Management

Management of sludge solids from an activated sludge system has been carried out in the U.S. and in Europe. This is being done to replace or improve sand drying beds. Reed beds have been found to provide shorter dewatering times and reduced sludge volumes and organic material.

Appendix B
Example Calculation Tables for SF and SSF Wetlands

Appendix B - Alberta Environmental Protection - Wetlands Guidelines

Surface Flow (SF) Treatment Wetland - Preliminary Feasibility Calculation Sheet - Example

Instructions: Fill in the single outline boxes with data gathered in Section 1, then calculate the values for the double outlined boxes.

Location: ______________________

Design Flow, m3/d — Q= 120

		TSS	BOD	TP	TN	NH4-N	Org-N	FC
Influent Concentration	C_i =	15	30	3	30	20	25	200,000
Target Effluent Concentration	C_e =	8.5	6	0.2	4	1	3	200
Wetland background limit, mg/L for TSS, $C^* = 7.8 + 0.063C_i$ for BOD, $C^* = 3.5+0.053C_i$	C^* =	8	5	0.05	2	0	1.5	100
Areal rate constant @ 20°C, m/yr.	k =	1000	34	12	22	18	17	77
Required wetland area, ha	A =	0.009	0.4	1.1	0.5	0.7	0.7	0.4

$$A = \left(\frac{0.0365 \times Q}{k}\right) \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

maximum calculated area from above boxes (A_{max}) = 1.1 ha

		TSS	BOD	TP	TN	NH4-N	Org-N	FC
Effluent concentration, mg/L via k-C* model	**C_o @ maximum area =**	8	5	0.20	2	0	2	100

$$C_o = C^* + (C_i - C^*)\exp\left(-\frac{kA_{max}}{0.0365 \times Q}\right)$$

Appendix B - Alberta Environmental Protection - Wetlands Guidelines

Subsurface Flow (SSF) Treatment Wetland - Preliminary Feasibility Calculation Sheet - Example

Instructions: Fill in the single outline boxes with data gathered in Section 1, then calculate the values for the double outlined boxes.

Location: ______________________

Design Flow, m^3/d **Q=** 120

		TSS	BOD	TP	TN	NH_4-N	Org-N	FC
Influent Concentration	C_i =	100	128	5	60	40	50	10,000,000
Target Effluent Concentration	C_e =	15	30	3	30	20	25	200,000
Wetland background limit, mg/L for TSS, $C^* = 7.8 + 0.063C_i$ for BOD, $C^* = 3.5+0.053C_i$	C^* =	14	10	0.05	2	0	1.5	100
Areal rate constant @ 20°C, m/yr.	k =	1000	34	12	22	18	17	77
Required wetland area, ha	A =	0.02	0.23	0.19	0.14	0.17	0.19	0.22

$$A = \left(\frac{0.0365 \times Q}{k}\right) \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

maximum calculated area from above boxes (A_{max}) = 0.23 ha

		TSS	BOD	TP	TN	NH_4-N	Org-N	FC
Effluent concentration, mg/L via k-C* model	**C_o @ maximum area =**	14	30	3	20	16	21	174,902

$$C_o = C^* + (C_i - C^*)\exp\left(-\frac{kA_{max}}{0.0365 \times Q}\right)$$

Appendix C

References For Wetland Evaluation Guidelines And Other Appendices

C. References for Wetland Evaluation Guidelines and Other Appendices

Alberta Department of Environmental Protection 1995. Alberta's Statement of the Environment: a Comprehensive Report. Publication I/583, Alberta Environmental Protection.

Alberta Water Resources Commission. 1993a. Wetland Management in the Settled Area of Alberta: an Interim Policy. Alberta Water Resources Commission, Edmonton.

Alberta Water Resources Commission. 1993b. Alberta's Peatlands and Non-Settled Area Wetlands: a Background Report. Alberta Water Resources Commission, Edmonton.

Allen, L. 1991. Status of Plant Conservation in Alberta. In Holroyd, G.L., G. Burns and H.C. Smith. 1991. Proceedings of the Second Endangered Species and Prairie Conservation Workshop. Provincial Museum of Alberta Natural History Occasional Paper No. 5.

Atkinson, D.W., Taylor, D., and Cheung, P. Stormwater Management Guidelines for the Province of Alberta. 1997.

Berry, D. 1995. Alberta's Walleye Management and Recovery Plan. Alberta Environmental Protection, Natural Resources Service, Fisheries Management Division.

Bramm, S. 1992. Protecting Ecosystems in Alberta: a Survey of Government Mechanisms. Environmental Council of Alberta, Edmonton, Alberta.

D.A. Westworth and Associates Ltd., 1993. Functions and Values of Alberta's Wetlands. Report for Wetlands Management Steering Committee. North Petroleum Plaza, Edmonton, Alberta.

D.A. Westworth and Associates Ltd. 1990. Significant Natural Features of the Eastern Boreal Forest Region of Alberta. Tech Report for Alberta Forestry, Lands and Wildlife.

Dickson, H.L. and A.R. Smith. 1991. The Western Hemisphere Shorebird Reserve Network and the Prairie Shorebird Program. In Holroyd, G.L., G. Burns and H.C. Smith. 1991. Proceedings of the Second Endangered Species and Prairie Conservation Workshop. Provincial Museum of Alberta Natural History Occasional Paper No. 5.

Environment Canada. 1982.

Kadlec, R.H. and R.L. Knight. Treatment Wetlands. Lewis Publishers. 1996.

Knight, R.L., Payne, V., Pries, J.H., Borer, R., Clarke, R. Constructed Wetlands for Livestock Wastewater Management - Literature Review, Database, and Research Synthesis. Gulf of Mexico Program. 1997.

Nietfield, M., J. Wilk, K. Woolnough and B. Hoskins. 1985. Wildlife Habitat Requirement Summaries for Selected Wildlife Species in Alberta. Alberta Energy and Natural Resources (ENR Technical Report T/73), Fish and Wildlife Division, Edmonton.

Packer, J.G. and C.E. Bradley. 1984. A checklist of the Rare Vascular Plants of Alberta. Provincial Museum of Alberta Occasional Paper No. 5.

Paetz, M.J. and J.S. Nelson. 1970. The Fishes of Alberta. Government of Alberta, Edmonton. 282 pp.

Posey, M. 1992. Saving the Strands of Life. Alberta's Biodiversity. Environmental Council of Alberta, Edmonton.

Poston, B., D.M. Ealey, P.S. Taylor and G.B. McKeating. 1990. Priority Migratory Bird Habitats of Canada's Prairie Provinces. Habitat Conservation Section, Canadian Wildlife Service, Western and Northern Region, Environment Canada, Edmonton, Alberta.

Pries, J.H. Wastewater and Stormwater Applications of Wetlands in Canada. Issues Paper, No. 1994-1. North American Wetlands Conservation Council (Canada). 1994.

Semenchuk, G.P. 1992. The Atlas of Breeding Birds of Alberta. Federation of Alberta Naturalists, P.O. Box 1472, Edmonton, Alberta.

Smith, H.C. 1993. Alberta Mammals: an Atlas and Guide. Provincial Museum of Alberta, Edmonton, Alberta.

Strong, W.L., B.K. Calverley, A.J. Richard and G.R. Stewart. 1993. Characterization of Wetlands in the Settled Areas of Alberta. Report for Wetlands Management Steering Committee, Edmonton, Alberta.

Usher, R. and J. Scarth. 1990. Alberta's Wetlands: Water in the Bank. Environmental Council of Alberta, Edmonton, Alberta.

Wallis, C. 1987. Critical, Threatened and Endangered Habitats in Alberta. In Holroyd, G.L., P.H.R. Stepney, G.C. Trottier, W.B. MacGillivray, D.M. Ealey and K.E. Eberhart. 1987. Endangered Species in the Prairie Provinces. Provincial Museum of Alberta Occasional Paper No. 9.

Wildlife Management Division. 1996. The Status of Alberta Wildlife. Alberta Environmental Protection, Natural Resources Service, Edmonton.

Appendix D
Potential Adverse Environmental Impacts And Mitigating Measures

D. Potential Adverse Environmental Impacts and Mitigating Measures

Direct effects	Indirect Effects	Mitigation
Increase in nutrient input		
Replacement of plants adapted to nutrient-poor conditions (e.g. bog, fen, shoreline and prairie plants; many rare) with plants adapted to nutrient-rich conditions (e.g. cattails, bulrushes; generally more common spp.).	Increase in nutrient input may result in eradication of some native plant communities, which are often adapted to a narrow range of nutrient conditions; weedy species which out-compete native species may invade.	Further pretreatment of incoming wastewater; construct multi-cell treatment wetland in series to reduce nutrient loadings in the initial cells to levels typical of pre-wastewater conditions.
Weedy species which out-compete native species may invade and establish dense stands.	Characteristically low sedge brood and/or foraging habitat for waterfowl, shorebirds and aquatic mammals may be replaced by dense tall stands; possible positive impact by increasing concealing cover.	Further pretreatment of incoming wastewater; weed control unlikely to be effective; construct multi-cell treatment wetland in series to reduce nutrient loadings in the initial cells to levels typical of pre-wastewater conditions.
Algal blooms shade out floating and submergent species.	Forage species for some waterfowl killed; impacts on rare submergents; unsightly, which may reduce public acceptance of treatment wetland.	Algae control; further pretreatment of incoming wastewater; construct multi-cell treatment wetland in series to reduce nutrient loadings in the initial cells to levels typical of pre-wastewater conditions.
Contaminated surface water may enter local aquifer through recharge.	Contamination of groundwater and nearby shallow wells.	Ensure constructed wetland is not in an area of significant recharge, or place liner to increase retention time before water enters aquifer; further pretreatment of incoming wastewater.
Change in water chemistry may decrease population of aquatic organisms (fish, invertebrates).	Higher trophic level animal populations may decrease since the affected aquatic organisms may be prey species for these animals.	Further pretreatment of incoming wastewater; construct multi-cell treatment wetland in series to reduce nutrient loadings in the initial cells to levels typical of pre-wastewater conditions.
General decrease in plant species diversity.	Concomitant decrease in wildlife species diversity.	Restoration of habitat by creating low grade slopes (no more than 1:10) in some areas where a variety of plants can recolonize, replanting shrubs and trees in areas peripheral to the wetland; confinement of impacts to least diverse areas.
Necessity of restricting access to the wetland.	Possible negative affects on public acceptance; but positive affects for wildlife.	Education and signage; provision of public access in acceptable (e.g. peripheral) parts of the wetland; enhancement of access elsewhere by provision of trails, other amenities.
Increase in hydroperiod		
Woody species tend to be killed off and replaced by herbaceous species.	Reduction of habitat for forest-dependent species; potential elimination of habitat for species requiring large tracts of unbroken habitat (i.e. protected interior areas away from forest edge); potential effect on rare forest species.	Enlarge habitat by tree-planting or allowing vegetation at forest edge (increasing the area of forest-interior); improve linkage with other habitats; incorporate upland areas that will support woody species into wetland design.

Direct effects	Indirect Effects	Mitigation
	Tree removal will affect the amount of sunlight reaching water and affect plant productivity and increase watercourse temperatures.	Plant trees in strategic parts of the wetland to minimize impact on water temperature; incorporate upland areas that will support woody species into wetland design.
Increase in flooded area; water levels are more consistent, with fewer fluctuations.	Potential positive impact for waterfowl by increasing permanence of wetland, area of standing water.	If waterfowl are to be discouraged from using the site due to stringent effluent requirements, design the wetland to minimize open water, grazing, nesting, and breeding areas.
	Flooding of nests over or near water; flooding of low bank burrows/nests; erosion of banks.	Create stable habitat above the floodline; specifically restore lost habitat.
	Downstream flooding at periphery of wetland with attendant social cost; reduced acceptance of treatment wetland.	Calculate hydraulic effects and determine if wetland area is sufficient to receive wastewater and natural inputs; construct storage to increase capacity; reconfigure outflow area to increase outflow capacity.
Flooding of lower littoral zone and potential elimination of zone of annual plant species (often rare) which germinate when water levels fall.	Elimination of brood habitat, mud flats used as foraging areas by shorebirds, waterfowl; increase in inundation time may eliminate some invertebrates.	Engineer shoreline (at periphery of wetland or on created habitat islands) with gradual grade (no more than 1:10) to promote zonation of emergent plant species; provide storage or alternate outfall during some seasons to simulate natural water level fluctuations; divert water to avoid mud flats and areas of late-germinating vegetation.
Creation of larger, deeper water body.	Invasion by larger predatory or destructive aquatic species which may eliminate existing species; e.g. bullfrogs may be a cause of decline in leopard frogs; carp have widespread impacts on wetland vegetation.	Erect carp barriers as appropriate; reconfigure outflow area to increase outflow capacity and reduce water levels.
Construction activities to improve treatment capability		
Soil disturbance promotes invasion by non-native species, which tend to eliminate native species and communities.	Potential elimination of shorter annual vegetation or mud flats, which often provide foraging and brood habitat for waterfowl, shorebirds.	Plant native vegetation soon after construction is finished, confine soil disturbance to already disturbed areas if possible.
Siltation of watercourses during construction resulting in "smothered" plants and animals due to the deposition of silt.	Impacts on germinating plants, fish, invertebrates; impacts on organisms at higher trophic levels.	Control siltation during construction with standard construction techniques.
Blasting may expose rocks soluble minerals that could potentially contaminate surface water supply.	Toxicity for many organisms.	Conduct geochemical analysis of bedrock, avoid blasting in contaminated areas.
Construction may impact disturbance-sensitive species.	Reduction in population.	Avoid construction during times when most sensitivity to disturbance occurs (mainly during breeding season).

APPENDIX E

RARE PLANT SPECIES

E. Rare Plant Species

A complete list of Alberta's rare flora (360 species) is found in Packer and Bradley (1984). This listing is being revised, but revisions are not yet complete. The following notes significant wetland species listed by D.A. Westworth and Associates Ltd., 1993.

PART 1
SIGNIFICANT PLANTS OF ALBERTA WETLANDS

Plant Species	Status	Wetland Type
Braun's Quillwort)*Isoetes echinospora*)	R	Lakes and ponds
Floating Bur-reed (*Sparganium fluctuans*)	R	Shallow Water
Blunt-leaved Pondweed (*Potamogeton obtusifolius*)	R	Lakes and Ponds
Widgeon-grass (*Ruppia maritima*)	R	Saline Lakes and Ponds
Flowering quillwort (*Lilaea scilloides*)	R	Slough margins and mudflats
Broad-leaved Arrowhead (*Sagittaria latifolia*)	R	Lakes and Ponds
Tall Manna Grass (*Glyceria elata*)	R	Wet Meadows
Prairie Cord Grass (*Spartina pectinata*)	R	Saline shores and Marshes
Porcupine Sedge (*Carex hystricina*)	R	Marshes
Kellog's Sedge (*Carex kelloggii*)	R	Stream banks/Lake margins
Nevada Bullrush (*Scirpus nevadensis*)	R	Alkaline Pond Margins
Geyer's Wild Onion (*Allium geyeri*)	R	Wet Meadows/Stream Banks
Western Blue Flag (*Iris missouriensis*)	En	Wet meadows/stream banks
Small White Water-lily (*Nymphaea tetragona*)	R	Ponds
Waterwort (*Elatine triandra*)	R	Muddy shores/shallow water
Low Yellow Evening-primrose (*Oenothera flava*)	R	Wetland margins/clay flats
Lance-leaved Loosestrife (*Lysimachia lanceolata*)	R	Lake and Pond margins
Water Speedwell *Veronica* (*catenata*)	R	Lake and pond margins
Downingia (*Downingia laeta*)	R	Alkaline margins of ponds
Tall Beggar's-Ticks (*Bidens frondosa*)	R	Lake and pond margins

Notes:

R = Rare
En = Endangered: species threatened with immediate extinction or extirpation because of human actions.

PART 2
PLANT SPECIES OF THREATENED OR ENDANGERED STATUS IN ALBERTA

Species	Status	Habitat	Reason for decline
Southwestern Alberta			
Allium geyeri	E (Allen 1991)[1]	Wet meadows and stream banks	Restricted distribution and habitat destruction
Castilleja cusickii	E (Allen 1991)	Moist meadows and grasslands	
Cypripedium montanum	E (Allen1991)	Moist woods	
Iris missouriensis	E (Allen 1991)	Moist meadows and stream banks	
Astralagus lotiflorus	T (Allen 1991)	Dry slopes and prairie	
Sand Dunes of Prairies and Parklands			
Cyperus schweinitzii	E (Allen 1991)	Sand dunes	Dune stabilization: these species adapted to active dunes
Tradescantia occidentalis	E (Allen 1991)	Sand dunes	
Abronia micrantha	T (Allen 1991)	Sand dunes	
Chenopodium subglabrum	T (Allen 1991)	Sand dunes	
Lygodesmia rostrata	T (Allen 1991)	Sand dunes	

Legend:
T = Threatened: species likely to become endangered if the pressures from human or natural causes making them vulnerable are not reversed.
E = Endangered: species threatened with immediate extinction or extirpation because of human actions.
[1]Allen, 1991 (Appendix C)

Appendix F

Landscape Types and Localities Potentially Indicative of Significant Plant Species

F. Landscape Types and Localities Potentially Indicative of Significant Plant Species

PART 1
RELATIVE OCCURRENCE OF LANDSCAPE TYPES BASED ON THE PRE-EUROPEAN EXTENT OF EACH TYPE IN ALBERTA
(FROM COTTONWOOD CONSULTANTS INC., 1983; IN WALLIS, 1987)

Landscape Type	Status	Landscape Type	Status
Grassland and Parkland Ecoregion			
Mixed Grassland			
Upland			
1. Glaciolacustrine	C	2. outwash/sand plain	C
3. ground moraine	C	4. hummocky moraine	C
5. dune field	O	6. eroded plain	R
7. solonetz/blow-outs	C	8. non-weak solonetz	C
Wetland			
9. wet meadow	C	10. shallow marsh	O
11. deep marsh/open water	R	12. open alkali wetland	O
Valley (R)			
13. meandering river. terrace	O	14. sinuous river terrace	O
15. eroded bedrock marine	O	16. eroded bedrock non-marine	C.
17. protected slope	C	18. abandoned channel	O
19. inactive terrace	C	20. springs: alkali	O
21. springs-fresh	R		
Other (R)			
22. turbid stream	C	23. clear stream	R
24. intermittent stream	C	25. permanent stream	O
Northern Fescue Grassland			
Upland (C)			
1. glaciolacustrine (fine)	C	2. outwash/sand plain	C
3. ground moraine	C	4. hummocky moraine	C
5. dune field	O	6. eroded plain	R
7. solonetz	C	8. non/weak solonetz	C
Wetland (O)			
9. wet meadow	C	10. shallow marsh	C.
11. deep marsh/open water	O	12. open alkali wetland	R
13. fresh/sl. alkali lake	C	14. alkali lake	C
Valley (R)			
15. meandering river terrace	R	16. sinuous river terrace	O
17. eroded bedrock	O	18. protected slope	C
19. inactive terrace	C	20. abandoned channel	R

PART 1
RELATIVE OCCURRENCE OF LANDSCAPE TYPES BASED ON THE PRE-EUROPEAN EXTENT OF EACH TYPE IN ALBERTA
(FROM COTTONWOOD CONSULTANTS INC., 1983; IN WALLIS, 1987)

Landscape Type	Status	Landscape Type	Status
21. springs: fresh	R	22. springs: alkali	O
Other (R)			
23. clear stream	R	24. turbid stream	C
25. permanent stream	O	25. intermittent stream	C
Foothills Grassland Ecoregion			
Plains (C)			
1. glaciolacustrine (fine)	O	2. outwash/sand plain	(C)
3. ground moraine	C	4. hummocky moraine	(C)
Valley/Hill (C)			
5. unglaciated	R	6. S or W-facing slope	C
7. N or E-facing slope	C	8. meandering river terrace	O
9. sinuous river terrace	O	10. eroded bedrock	R
Wetland (O)			
11. wet meadow	C	12. shallow marsh	C
13. deep marsh/open water	O	14. abandoned channel	O
15. seepage/springs	O		
Other (R)			
16. clear stream	C	17. turbid stream	O
18. permanent stream	C	19. intermittent stream	C
Central Parkland Ecoregion			
Upland (C)			
1. glaciolacustrine (fine)	C	2. outwash/sand plain	C
3. ground moraine	C	4. hummocky moraine	C
5. dune field	O	6. kame moraine	R
7. solonetz	C	8. non/weak solonetz	C
Wetland (C)			
9. wet meadow	C	10. shallow marsh	C
11. deep marsh/open water	C	12. open alkali wetland	O
13. fresh/sl. alkali lake	C	14. alkali lake	C
Valley (R)			
15. meandering river terrace	O	16. sinuous river terrace	O
17. eroded bedrock	O	18. protected slope	C
19. slump	O	20. abandoned channel	O
21. springs: fresh	O	22. springs: alkali	O
Other (R)			
23. clear stream	C	24. permanent stream	C
25. intermittent stream	C		

PART 1
RELATIVE OCCURRENCE OF LANDSCAPE TYPES BASED ON THE PRE-EUROPEAN EXTENT OF EACH TYPE IN ALBERTA
(FROM COTTONWOOD CONSULTANTS INC., 1983; IN WALLIS, 1987)

Landscape Type	Status	Landscape Type	Status
Foothills Parkland Ecoregion			
Plains (O)			
1. glaciolacustrine (fine)	O	2. outwash/sand plain	
3. ground moraine	C	4. hummocky moraine	
Valley/Hill (C)			
5. meandering river terrace	O	6. sinuous river terrace	O
7. eroded bedrock	O	8. small stream valley	C
9. protected slopes	C		
Wetland (O)			
10. wet meadow	C	11. shallow marsh	C
12. deep marsh/open water	C	13. abandoned channel	O
14. seepage/springs	C		
Other (R)			
15. clear stream	C	16. turbid stream	O

Legend:
R = Rare
O = Occasional
C = Common

PART 2
EXAMPLES OF INDIVIDUALLY NOTED SIGNIFICANT LANDSCAPES OR PLANT COMMUNITIES IN GRASSLAND, PARKLAND, AND BOREAL REGIONS (WALLIS, 1987; D.A. WESTWORTH & ASSOCIATES, 1990, BRAMM, 1992: SEE APPENDIX C))

Location	Feature
Foothills Parkland/Foothills Grassland	
Southernmost portion of the foothills parkland in the Waterton/Paine Lake area	The largest concentration of plants rare or at periphery of range: unglaciated area
Little Bluestem prairie located northwest of Fort MacLeod	Vegetation representative of presettlement prairie
Wet meadow site in Police Outpost Provincial Park	Wet meadow with endangered plant species
The Ross Lake area of the Milk River Ridge	Prime area of presettlement foothills grassland
Mineral Springs along Boundary Creek	Rare plant species
Oldman and Belly Rivers	The most extensive narrow-leaved cottonwood stands in Canada
Big Hill Springs Provincial Park	Rare plant species
Central Parkland	
Hummocky moraine near Rumsey	Largest remaining Modal site aspen parkland in the world
Sounding Lake and Reflex Lake sand plain areas	Kame moraine, outwash/sand plain, dune field, non/weak solonetz, deep marsh/open water, fresh/sl. alkaline lake
Wainwright-David Lake-Ribstone Creek area	high diversity of landform as well as rare slope fens, shrub fens with rare plant species, active blow-outs
Neutral Hills-Goosberry Lake-Bodo	Sizeable areas of Central Parkland on morainal landscapes
Miquelon Lake Provincial Park	Some of the best closed forest in the Cooking Lake Moraine area
Dry Island Buffalo Jump Provincial Park	Diverse section of Red Deer River Valley including coniferous forest, badlands and slump block features
Mixed Grassland	
Milk River-Lost River area	last remaining ungrazed vegetation associated with springs and creeks; numerous plants at northern edge of range; Mountain Plover breeding habitat
Middle Sand Hills Sand Dunes	Largest sand dune area in grassland region; numerous rare or restricted species in excellent condition; landscape of Canadian significance
Between the Milk River Canyon and Suffield areas: outwash/sand plain	Wide variety of landscape types (including dunes, wetlands, bedrock outcrops, streams) with attendant wide diversity of plant communities.
Empress Region	The only active sand dunes in the Grassland region outside Suffield Military Reserve; habitat for high quality native vegetation
McTaggart Coulee and Black Butte	Porphyry with rare lichens
Writing-on-Stone Provincial Park	extensive areas of massive sandstone outcrops with rare plant and animal species
Dinosaur Provincial Park	High variety and quality of badlands and riparian vegetation; one of the few examples of ungrazed riparian woodland in the Grassland region

PART 2
EXAMPLES OF INDIVIDUALLY NOTED SIGNIFICANT LANDSCAPES OR PLANT COMMUNITIES IN GRASSLAND, PARKLAND, AND BOREAL REGIONS (WALLIS, 1987; D.A. WESTWORTH & ASSOCIATES, 1990, BRAMM, 1992: SEE APPENDIX C))

Location	Feature
Terraces along lower Red Deer near Bindloss	Largest in Grassland Region; most extensive and diverse variety and quality of riparian habitats in Alberta; Alkali springs with rare associated Manitoba Maple woodlands
South of Empress along the South Saskatchewan River	Best example of Manitoba Maple woodland with rich understorey containing rare plant species
Duchess Springs	Most extensive spring woodlands in Grassland Region
Douglas Creek adjacent to the Red Deer River	Extensive areas of spring seepage vegetation
Northern Fescue Grassland	**Note: one of the most endangered biogeographic regions on the Canadian Plains**
Little Fish-Hand Hills-Wintering Hills area	Last large remnants of Northern Fescue Grassland; good representation of landforms; rare plants
Cypress Hills	Unglaciated plateau unlike any other area in the plains of Canada; disjunct Montane vegetation with southern affinities; relict post-glacial forest flora
Eastern Boreal Region	Many significant sites identified for a wide variety of reasons (D.A. Westworth and Associates, 1990) Features considered generally significant include ombrotrophic bogs, karst features
Canadian Shield	Generally, little is known about significant features in this region (Bramm 1992)
Kazan Upland	Disjunct or rare plant species
Athabasca Plain	Active sand dunes among the largest in the world; diverse dune forms, palaeodunes and kames; plant species not found elsewhere in Alberta

Appendix C

Habitat Matrix for Breeding Fishes, Amphibians and Reptiles, Birds, and Mammals of Alberta

APPENDIX G
PART 1: HABITAT MATRIX FOR FISHES OF ALBERTA

	Wetland Habitat							Open water habitat						Special Needs (an asterisk in this column indicates that the species is unlikely to be affected by a treatment wetland under guidelines proposed here)
	Marsh				Swamp									
***In this column indicates area-or disturbance-sensitive species**	cattail	graminoid	low shrub	bog	tall shrub	coniferous	deciduous	lake	pond	river	stream			
Changes expected as a result of wastewater inflow														
Habitat before inflows	*	*	*	*	*	*	*		*					
Habitat after inflows	*	*												
Species														
Lake Sturgeon								*		*				*
Arctic Grayling								*						*
Cisco								*						*
Shortjaw Cisco								*						*
Lake Whitefish								*						*
Mountain Whitefish											*			*
Lake Trout								*						*
Bull Trout								*						*
Brook Trout					*			*		*	*			clear, cold water
Brown Trout					*			*		*	*			clear, cold water
Cutthroat Trout										*	*			clear, cold water
Rainbow Trout										*	*			cool water
Golden Trout														clear, cold water
Kokanee														cool water
Northern Pike	*	*								*	*			spawn in shallow, seasonally flooded marshes
Goldeye								*		*				
Longnose Dace								*	*	*	*			
Flathead Chub										*				often inhabit river margins
Lake Chub								*		*	*			
Pearl Dace	*	*	*		*			*			*			
Northern Squawfish								*						*
Redside Shiner										*				
Northern Redbelly Dace		*						*			*			spawn over aquatic plants
Finescale Dace	*	*			*			*			*			
Fathead Minnow	*	*	*		*			*	*		*			
Emerald Shiner								*		*				*
River Shiner											*			sandy or gravelly substrate
Spottail Shiner								*			*			*
Brassy Minnow										*	*			*
Silvery Minnow											*			* intolerant of turbid water
Quillback										*				*
Silver Redhorse								*		*				*
Northern Redhorse								*		*	*			*
Longnose Sucker								*		*				*
White Sucker	*							*		*				spawn on sandy substrate
Largescale Sucker										*				*
Mountain Sucker											*			* swift-flowing mountain streams

APPENDIX G
PART 1: HABITAT MATRIX FOR FISHES OF ALBERTA

	Wetland Habitat							Open water habitat							Special Needs (an asterisk in this column indicates that the species is unlikely to be affected by a treatment wetland under guidelines proposed here)
	Marsh				Swamp										
***In this column indicates area-or disturbance-sensitive species**	cattail	graminoid	low shrub	bog	tall shrub	coniferous	deciduous	lake	pond	river	stream				
Stonecat															* streams with current
Burbot								*			*				*
Trout-Perch								*		*					*
Brook Stickleback	*	*	*	*	*			*	*		*				
Ninespine Stickleback								*							*
Iowa Darter	*	*	*		*			*			*				
Yellow Perch								*		*					
Sauger										*					*
Walleye								*		*					*
Mottled Sculpin											*				*
Slimy Sculpin								*			*				*
Spoonhead Sculpin								*		*					*

APPENDIX G
PART 2: HABITAT MATRIX FOR BREEDING AMPHIBIANS AND REPTILES

	Lowland Habitat							Upland Habitat							Special Needs
	Marsh				Swamp			Open		woodland					
***In this column indicates area-or disturbance-sensitive species**	cattail	graminoid	low shrub	bog	tall shrub	coniferous	deciduous	grassland	scrubland	young deciduous	mixed	mature deciduous	young coniferous	mature coniferous	
Changes expected as a result of wastewater inflow															
Habitat before inflows	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Habitat after inflows	*	*													
Species															
Great Plains Toad								*							Flooded areas in spring for breeding
Northern Leopard Frog	*	*	*		*										Spring pools for breeding
Wood Frog				*	*	*					*	*	*	*	Flooded areas for breeding
Plains Spadefoot Toad								*							Flooded areas for breeding
Spotted Frog	*	*	*		*										Montane areas; flooded areas for breeding
Canadian Toad					*		*	*	*	*					Water bodies
Boreal toad				*		*					*		*	*	Flooded areas for breeding
Chorus Frog	*	*						*	*						Flooded areas for breeding
Long-toed Salamander			*		*	*	*								Riparian areas in mountains
Tiger Salamander	*	*						*	*	*		*			Concealing cover (debris)
Short-horned Lizard															
Western Hognose Snake								*	*						
Prairie Rattlesnake*								*	*						River valley slopes for hibernation
Western Painted Turtle								*	*						Permanent standing water
Bull Snake								*							Winter den sites
Plains Garter Snake	*	*	*		*			*	*	*					Generally near water
Red-sided Garter Snake				*	*	*	*				*	*	*	*	Permanent water
Wandering Garter Snake	*	*	*		*		*	*	*	*	*	*			

APPENDIX G

PART 3: HABITAT MATRIX FOR BREEDING BIRDS OF ALBERTA (information adapted from Semenchuk, 1992)

	Lowland Habitat							Upland Habitat							
	Marsh				Swamp			Open		Woodland					
*In this column indicates area-or disturbance-sensitive species	Cattail	Graminoid	Low shrub	Bog	Tall shrub	Coniferous	Deciduous	Grassland	Scrubland	Young Deciduous	Mixed	Mature Deciduous	Young Coniferous	Mature Coniferous	Special Needs
Changes expected as a result of wastewater inflow															
Habitat before inflows	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Habitat after inflows	*	*													
Species															
Red-throated Loon*	*	*													Deep water
Pacific Loon*				*											Northern: Deep water
Common Loon*	*	*	*	*											Large, deep lakes
Pied-billed Grebe*	*	*		*											Large, deep lakes
Horned Grebe	*	*													Large, marshy lakes
Red-necked Grebe*	*	*													Colonial: marshy lakes
Eared Grebe*	*	*													Large, shallow lakes
Western Grebe*	*	*													Colonial: marshy lakes
Clarke's Grebe*	*	*													Colonial: marshy lakes
American White Pelican*	*	*	*												Colonial: on islands in lakes with fish
Double-crested Cormorant*	*	*	*												Colonial: on islands in lakes with fish
American Bittern*	*	*	*	*	*										Tall vegetation
Great Blue Heron*						*	*					*	*		Open marsh nearby
Black-crowned Night Heron*	*	*			*	*	*			*		*	*		Open marsh nearby
White-faced Ibis*		*													Mudflats
Trumpeter Swan	*	*													Large, marshy lakes
Canada Goose	*	*	*	*		*	*	*		*		*	*	*	Usually open water
Wood Duck										*		*			Large dead trees, brood habitat
Green-winged Teal								*	*						Open water nearby, brood habitat
Mallard	*	*	*	*	*										Open water nearby, brood habitat
Northern Pintail								*							Open water nearby, brood habitat
Blue-winged Teal								*							Open water nearby, brood habitat
Cinnamon Teal	*	*						*							Open water, brood habitat nearby
Northern Shoveler								*							Open water, brood habitat nearby
Gadwall								*	*						Open water, brood habitat nearby
American Widgeon*								*	*						Water, brood habitat nearby
Canvasback*	*	*													Water, brood habitat nearby

APPENDIX G
PART 3: HABITAT MATRIX FOR BREEDING BIRDS OF ALBERTA (information adapted from Semenchuk, 1992)

	Lowland Habitat							Upland Habitat							
	Marsh				Swamp			Open		Woodland					
*In this column indicates area-or disturbance-sensitive species	Cattail	Graminoid	Low shrub	Bog	Tall shrub	Coniferous	Deciduous	Grassland	Scrubland	Young Deciduous	Mixed	Mature Deciduous	Young Coniferous	Mature Coniferous	Special Needs
Redhead	*	*													Marshy lakes
Ring-necked Duck	*	*	*	*											Shallow lakes
Lesser Scaup		*						*							Large marshy lakes
Harlequin Duck *				*	*										Fast mountain streams
Surf Scoter*				*	*								*		Open water with woody cover
White-winged Scoter*	*	*	*	*				*	*						Open water, brood habitat; undisturbed islands
Common Goldeneye*						*	*					*		*	Large dead trees, brood habitat
Barrow's Goldeneye*						*	*					*		*	Large dead trees, brood habitat
Bufflehead						*	*					*		*	Large dead trees, brood habitat
Hooded Merganser						*	*					*		*	Large dead trees, deep water
Common Merganser						*	*					*		*	Large dead trees, deep water
Red-breasted Merganser*										*		*	*	*	Shorelines, deep water
Ruddy Duck	*	*	*												Open water, brood habitat
Turkey Vulture*										*	*	*			Rocky outcrops, near water
Osprey*	*	*	*		*	*	*	*	*	*	*	*	*	*	Tall structures, near fish
Bald Eagle*												*		*	Tall structures, near fish
Northern Harrier*	*	*						*	*						Open country
Sharp-shinned Hawk											*	*		*	
Cooper's Hawk*											*	*		*	Often near water
Northern Goshawk*											*	*		*	
Broad-winged Hawk*											*	*		*	
Swainson's Hawk								*	*						Tall trees
Red-tailed Hawk								*	*	*	*	*	*	*	Open country nearby
Ferruginous Hawk*								*							Sparsely treed areas
Golden Eagle*								*							Sparsely treed areas, slopes or plateaus
American Kestrel								*	*	*	*	*	*	*	Open country nearby, nest cavities
Merlin				*		*			*	*	*	*	*	*	Open country nearby
Peregrine Falcon*								*	*						Cliffs
Prairie Falcon*								*	*						Cliffs
Gray Partridge								*	*						Adjacent woods
Ring-necked Pheasant								*	*	*			*		
Spruce Grouse*				*							*		*	*	
Blue Grouse*											*		*	*	Mountains
Willow Ptarmigan*			*	*	*										Above timberline
White-tailed Ptarmigan*								*							Alpine meadows
Ruffed Grouse											*	*			Small openings
Sage Grouse*									*						Sagebrush, dense river bottoms

APPENDIX G
PART 3: HABITAT MATRIX FOR BREEDING BIRDS OF ALBERTA (information adapted from Semenchuk, 1992)

	Lowland Habitat							Upland Habitat							
	Marsh				Swamp			Open		Woodland					
*In this column indicates area-or disturbance-sensitive species	Cattail	Graminoid	Low shrub	Bog	Tall shrub	Coniferous	Deciduous	Grassland	Scrubland	Young Deciduous	Mixed	Mature Deciduous	Young Coniferous	Mature Coniferous	Special Needs
Sharp-tailed Grouse				*	*			*	*	*					
Wild Turkey										*	*	*			Not native to Alberta
Yellow Rail*		*													Colonial
Virginia Rail	*	*													
Sora	*	*	*												
American Coot	*	*													Open water
Sandhill Crane*	*	*		*											
Whooping Crane*	*	*													
Semipalmated Plover*															Sand, gravel shores
Piping Plover*															Sandy shores of saline lakes
Killdeer															Sand and gravel
Mountain Plover*								*							Short grassland
Black-necked Stilt*		*													Mudflats
American Avocet*		*													Mudflats
Greater Yellowlegs*			*	*	*	*									
Lesser Yellowlegs*				*						*	*		*		Water, brood habitat
Solitary Sandpiper*					*	*									
Willet		*						*							Water
Spotted Sandpiper	*	*	*												
Upland Sandpiper*		*						*							
Long-billed Curlew*								*							Brood habitat
Marbled Godwit*		*						*							Low grass, water
Least Sandpiper*		*		*											
Short-billed Dowitcher*		*		*											Low vegetation
Common Snipe		*	*	*	*										Open areas nearby
Wilson's Phalarope		*													Open water
Red-necked Phalarope*		*		*											Open water
Franklin's Gull*	*														Open water
Bonaparte's Gull*				*		*							*	*	Open water
Mew Gull*	*														Open water
Ring-billed Gull															Islands, open water
California Gull															Rocky islands in lakes
Herring Gull															Rocky islands in lakes; colonial
Caspian Tern															Rocky islands in lakes
Common Tern															Sandy shores of lakes
Forster's Tern*	*														
Black Tern*	*	*													
Rock Dove															Nests in human structures
Mourning Dove								*	*		*		*	*	Often near water

APPENDIX G

PART 3: HABITAT MATRIX FOR BREEDING BIRDS OF ALBERTA (information adapted from Semenchuk, 1992)

	Lowland Habitat							Upland Habitat							
	Marsh				Swamp			Open		Woodland					
*In this column indicates area-or disturbance-sensitive species	Cattail	Graminoid	Low shrub	Bog	Tall shrub	Coniferous	Deciduous	Grassland	Scrubland	Young Deciduous	Mixed	Mature Deciduous	Young Coniferous	Mature Coniferous	Special Needs
Black-billed Cuckoo					*				*						Dense underbrush
Great Horned Owl						*	*			*	*	*	*	*	
Northern Hawk Owl*						*					*			*	
Northern Pigmy Owl											*			*	Adjacent small clearings
Burrowing Owl*								*							
Barred Owl*											*			*	Nest cavities
Great Gray Owl*														*	
Long-eared Owl											*	*		*	Near water
Short-eared Owl*								*							
Boreal Owl											*			*	
Northern Saw-whet owl											*	*			Nest cavities
Common Nighthawk								*							Open ground
Black Swift*															Montane cliffs near waterfalls
Ruby-throated Hummingbird							*			*	*	*			Open woodlands
Calliope Hummingbird*					*					*	*	*	*	*	Open montane woodlands
Rufous Hummingbird						*	*			*	*	*	*	*	Adjacent to openings with flowers
Belted Kingfisher								*	*	*	*	*	*	*	Burrows near water
Yellow-bellied Sapsucker							*				*	*			Nest cavities near openings
Red-naped Sapsucker							*				*	*			Nest cavities
Downy woodpecker						*	*			*	*	*	*		Nest cavities
Hairy Woodpecker*						*	*			*	*	*	*	*	Nest cavities
Three-toed Woodpecker*						*					*			*	Nearby openings; nest cvities
Black-backed Woodpecker*						*					*			*	Dense forest; nest cavities
Northern Flicker						*	*				*	*		*	Nest cavities
Pileated Woodpecker							*				*	*			Nest cavities
Olive-sided Flycatcher*				*		*					*		*	*	Semi-open forest near water
Western Wood-Pewee						*	*			*	*	*	*	*	
Yellow-bellied Flycatcher*				*		*	*						*	*	
Alder Flycatcher			*		*				*						Near water
Willow Flycatcher			*		*				*						Usually near water
Least Flycatcher						*	*			*	*	*	*	*	Open woodland
Hammond's Flycatcher*													*	*	
Dusky Flycatcher*					*				*	*	*				Open woodland
Cordilleran Flycatcher						*	*				*	*	*	*	Open woodland
Eastern Phoebe						*	*			*	*	*	*	*	Structures near water
Say's Phoebe*								*	*						Sheltered area with overhang
Great Crested Flycatcher											*	*			Nest cavities
Western Kingbird								*							Tall perches
Eastern Kingbird		*	*	*	*			*	*						Tall perches, openings

APPENDIX G
PART 3: HABITAT MATRIX FOR BREEDING BIRDS OF ALBERTA (information adapted from Semenchuk, 1992)

	Lowland Habitat							Upland Habitat							
	Marsh				Swamp			Open		Woodland					
*In this column indicates area-or disturbance-sensitive species	Cattail	Graminoid	Low shrub	Bog	Tall shrub	Coniferous	Deciduous	Grassland	Scrubland	Young Deciduous	Mixed	Mature Deciduous	Young Coniferous	Mature Coniferous	Special Needs
Horned Lark								*	*	*					Open ground
Purple Martin						*	*				*			*	Adjacent open areas
Tree Swallow				*	*	*	*					*		*	Nest cavities near water; adjacent openings
Violet-green Swallow			*	*	*	*	*								Nest cavities near water and openings
Northern Rough-winged Swallow		*	*					*							Banks and open land near water
Bank Swallow								*	*	*	*		*		Banks near water
Cliff Swallow								*	*	*	*		*		Cliffs near water
Barn Swallow	*	*	*	*				*	*						Structures near water
Gray Jay*				*		*					*		*	*	Dense Forests
Steller's Jay*														*	Montane and lower subalpine regions
Blue Jay						*					*	*			
Clarke's Nutcracker														*	Openings
Black-billed Magpie								*	*	*	*	*	*		Nest trees
American Crow				*	*	*	*		*	*	*	*	*	*	
Common Raven*						*					*			*	
Black-capped Chickadee					*	*	*		*	*	*	*	*	*	Nest cavities
Mountain Chickadee*											*			*	Nest cavities; open woods
Boreal Chickadee*				*		*					*		*	*	
Red-breasted Nuthatch*						*					*			*	
White-breasted Nuthatch						*	*				*	*		*	
Brown Creeper*						*					*			*	
Rock Wren*								*							Areas with sparse vegetation; rock outcrops
House Wren				*	*				*	*			*		Nest cavities
Winter Wren*						*					*			*	
Sedge Wren		*	*	*	*			*	*						Near water
Marsh Wren*	*	*													
American Dipper*												*		*	Rock ledges over flowing water
Golden-crowned Kinglet*						*					*			*	
Ruby-crowned Kinglet*						*					*			*	
Eastern Bluebird								*	*	*			*		Nest cavities
Western Bluebird*							*		*						Snags; sparse tree cover
Mountain Bluebird							*			*		*	*		Nest cavities, openings
Townsend's Solitaire*														*	Mountains and foothills
Veery*							*			*	*	*			Shrubby understory
Swainson's Thrush*							*							*	

APPENDIX G
PART 3: HABITAT MATRIX FOR BREEDING BIRDS OF ALBERTA (information adapted from Semenchuk, 1992)

	Lowland Habitat							Upland Habitat							
	Marsh				Swamp			Open		Woodland					
*In this column indicates area-or disturbance-sensitive species	Cattail	Graminoid	Low shrub	Bog	Tall shrub	Coniferous	Deciduous	Grassland	Scrubland	Young Deciduous	Mixed	Mature Deciduous	Young Coniferous	Mature Coniferous	Special Needs
Hermit Thrush*						*	*		*		*	*		*	
American Robin						*	*			*	*	*	*	*	Openings
Varied Thrush*						*								*	Dense understory
Gray Catbird					*				*	*			*		
Northern Mockingbird					*				*	*			*		
Sage Thrasher*								*							Sagebrush
Brown Thrasher					*				*	*			*		
American Pipit*			*					*							Above timberline
Sprague's Pipit*								*	*						
Bohemian Waxwing*											*			*	Openings
Cedar Waxwing					*		*		*	*	*				
Northern Shrike*				*		*							*	*	Open woods
Loggerhead Shrike*					*				*						Thorn bushes
European Starling							*			*	*	*			Cavities; highly adaptable
Solitary Vireo*											*			*	
Warbling Vireo							*			*	*	*			
Philadelphia Vireo*					*		*		*	*	*	*			
Red-eyed Vireo					*		*				*	*			
Tennessee Warbler*					*		*			*	*	*			
Orange-crowned Warbler*					*					*					
Nashville Warbler				*					*		*		*		
Yellow Warbler			*		*				*	*	*		*		
Chestnut-sided Warbler					*				*	*	*		*		
Magnolia Warbler			*			*			*		*		*		
Cape May Warbler*											*			*	Tall song perches
Yellow-rumped Warbler*				*		*								*	Some deciduous trees; open woods
Townsend's Warbler*						*								*	Dense canopy, water nearby
Black-throated Green Warbler						*					*			*	
Blackburnian Warbler*											*			*	
Palm Warbler*			*	*	*	*	*								
Bay-breasted Warbler*						*							*	*	
Blackpoll Warbler*						*			*		*			*	
Black-and-white Warbler*				*	*	*					*	*			
American Redstart					*		*			*	*	*			
Ovenbird*											*	*			Sparse understory
Northern Waterthrush*					*		*				*	*			Near water
Connecticut Warbler*				*							*	*			Sparse understorey

APPENDIX G
PART 3: HABITAT MATRIX FOR BREEDING BIRDS OF ALBERTA (information adapted from Semenchuk, 1992)

	Lowland Habitat							Upland Habitat							
	Marsh				Swamp			Open		Woodland					
*In this column indicates area-or disturbance-sensitive species	Cattail	Graminoid	Low shrub	Bog	Tall shrub	Coniferous	Deciduous	Grassland	Scrubland	Young Deciduous	Mixed	Mature Deciduous	Young Coniferous	Mature Coniferous	Special Needs
Mourning Warbler			*		*							*			Open canopy; dense understory
MacGillivray's Warbler*					*				*						Dense understory
Common Yellowthroat	*		*	*	*										
Wilson's Warbler*					*		*		*						Near water
Canada Warbler*					*		*				*	*			Near water
Yellow-breasted Chat					*				*	*					
Western Tanager*											*			*	Open woodlands
Rose-breasted Grosbeak										*	*	*			
Black-headed Grosbeak										*	*	*			
Lazuli Bunting					*				*	*					Dense undergrowth
Rufous-sided Towhee					*				*	*					
American Tree Sparrow*			*		*										
Chipping Sparrow											*		*	*	
Clay-coloured Sparrow			*	*				*	*						
Brewer's Sparrow*								*	*				*		Sagebrush
Vesper Sparrow								*							
Lark Sparrow*								*	*						
Lark Bunting*								*							
Savannah Sparrow		*						*	*						
Baird's Sparrow*								*							Abundant matted grasses; intolerant of grazing
Grasshopper Sparrow*								*							
LeConte's Sparrow		*	*	*											
Sharp-tailed Sparrow		*													
Fox Sparrow*					*				*				*		
Song Sparrow			*	*	*	*	*		*	*	*	*	*	*	
Lincoln's Sparrow*			*	*	*										
Swamp Sparrow	*	*	*	*	*										
White-throated Sparrow				*	*	*			*		*		*		
Golden-crowned Sparrow*									*				*		Montane habitats
White-crowned Sparrow*				*	*				*				*		
Dark-eyed Junco				*	*	*			*		*			*	
McCown's Longspur*								*							Short grass
Chestnut-collared Longspur*								*							
Bobolink								*							
Red-winged Blackbird	*	*	*	*	*										
Western Meadowlark*								*	*						
Yellow-headed Blackbird	*														

APPENDIX G
PART 3: HABITAT MATRIX FOR BREEDING BIRDS OF ALBERTA (information adapted from Semenchuk, 1992)

	Lowland Habitat							Upland Habitat							
	Marsh				Swamp			Open		Woodland					
*In this column indicates area-or disturbance-sensitive species	Cattail	Graminoid	Low shrub	Bog	Tall shrub	Coniferous	Deciduous	Grassland	Scrubland	Young Deciduous	Mixed	Mature Deciduous	Young Coniferous	Mature Coniferous	Special Needs
Rusty Blackbird*				*	*	*									
Brewer's Blackbird*					*				*						
Common Grackle				*	*	*			*				*		
Brown-headed Cowbird	*				*			*	*	*	*		*		Open areas; brood Parasite
Northern Oriole							*			*	*	*			
Rosy Finch*			*					*							Outcrops in mountains
Pine Grosbeak*						*					*			*	
Purple Finch											*		*	*	
Cassin's Finch														*	Open montane forests
House Finch									*	*	*				
Red Crossbill*											*			*	
White-winged Crossbill*											*			*	
Common Redpoll*					*		*			*	*				
Pine Siskin											*	*		*	
American Goldfinch			*		*				*	*					
Evening Grosbeak*											*		*	*	
House Sparrow															Human habitation

APPENDIX G

PART 4: HABITAT MATRIX FOR MAMMALS OF ALBERTA (adapted from Smith 1993)

	Lowland Habitat							Upland Habitat							Special Needs
	Marsh				Swamp			Open		woodland					
***In this column indicates area-or disturbance-sensitive species**	cattail	graminoid	low shrub	bog	tall shrub	coniferous	deciduous	grassland	scrubland	young deciduous	mixed	mature deciduous	young coniferous	mature coniferous	
Changes expected as a result of wastewater inflow															
Habitat before inflows	*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Habitat after inflows	*	*													
Species															
Masked Shrew					*	*	*	*	*	*	*	*	*	*	Debris
Prairie Shrew*								*	*	*					
Dusky Shrew*		*	*	*	*	*	*		*	*	*	*	*	*	Dense Cover
Wandering Shrew*														*	Mountain streams
Water Shrew*										*	*	*	*	*	Creeks, ponds and lakes
Arctic Shrew*				*	*	*	*			*	*	*	*	*	
Pygmy Shrew*												*		*	
Little Brown Bat						*	*			*	*		*		Caves for hiberacula
Northern Long-eared Bat*											*			*	Caves for hibernacula
Long-eared Bat*								*	*						Sheltering rock outcrops
Long-legged Bat*									*	*	*	*	*	*	Rocky outcrops and caves
Western Small-footed Bat*								*							Rock outcrops and crevices in badlands
Silver-haired Bat*										*	*	*	*	*	
Big Brown Bat					*	*	*	*	*	*	*	*			Caves and crevices, buildings
Red Bat									*	*	*		*		
Hoary Bat*										*	*	*	*	*	
Pika*															Rock slides and talus slopes
Nuttal's Cottontail*								*	*						River bottomland and rocky valleys
Snowshoe Hare*									*	*	*	*	*	*	
White-tailed Jack Rabbit*								*							Open areas
Least Chipmunk*								*	*	*	*	*	*		
Yellow-pine Chipmunk*														*	Mountains: forest openings and clearings
Red-tailed Chipmunk*											*			*	Between 1500 and 2100 metres
Woodchuck								*	*	*	*				
Yellow-bellied Marmot*															Rocky outcrops
Hoary Marmot*								*							Mountains
Richardson's Ground Squirrel								*							Gravelly or sandy soils
Columbian Ground Squirrel*								*							Mountain meadows and bottomlands
Thirteen-lined Ground Squirrel*									*	*					
Franklin's Ground Squirrel*								*	*	*					

APPENDIX G

PART 4: HABITAT MATRIX FOR MAMMALS OF ALBERTA (adapted from Smith 1993)

	Lowland Habitat							Upland Habitat							Special Needs
	Marsh				Swamp			Open		woodland					
***In this column indicates area-or disturbance-sensitive species**	cattail	graminoid	low shrub	bog	tall shrub	coniferous	deciduous	grassland	scrubland	young deciduous	mixed	mature deciduous	young coniferous	mature coniferous	
Golden-mantled Ground Squirrel*									*	*	*	*			Mountains
Gray Squirrel										*	*	*			
Red Squirrel											*		*	*	
Northern Flying Squirrel*											*		*	*	Nest Cavities
Northern Pocket Gopher*								*							
Olive-backed Pocket Mouse*								*							Sandy soil
Ord's Kangaroo Rat*								*							Sandy soil, sparse vegetation
Beaver	*	*	*	*	*	*	*								Deep open water
Western Harvest Mouse*								*	*						
Deer Mouse					*	*	*	*	*	*	*	*	*	*	
Northern Grasshopper Mouse*								*							Sagebrush
Bushy-tailed Woodrat*															Rock slides, caves and crevices
Southern Red-backed Vole*					*	*	*			*	*	*	*	*	
Heather Vole*			*	*	*	*	*		*		*		*	*	
Meadow Vole		*						*	*						
Long-tailed Vole*		*													Mountains
Taiga Vole*															Horsetails
Prairie Vole*								*							Habitat enclosed by aspen
Water Vole*															Alpine meadows near streams
Sagebrush Vole*								*	*						Sagebrush
Muskrat	*	*	*												Permanent water
Brown Lemming*		*	*												Mountains
Northern Bog Lemming*		*	*	*											
Black Rat															Human habitation
Norway Rat															Human habitation
House Mouse									*						Human habitation
Meadow Jumping Mouse*		*													
Western Jumping Mouse*			*		*										
Porcupine*											*			*	
Coyote						*	*	*	*	*	*		*		
Gray Wolf*						*	*		*			*		*	
Arctic Fox*													*	*	Open areas
Red Fox					*	*	*	*	*	*	*	*	*	*	
Swift Fox*								*							
Gray Fox*										*		*			
Black Bear*											*		*	*	
Grizzly Bear*								*	*						
Raccoon							*	*	*	*	*	*			
Marten*														*	
Fisher*														*	

APPENDIX G

PART 4: HABITAT MATRIX FOR MAMMALS OF ALBERTA (adapted from Smith 1993)

	Lowland Habitat							Upland Habitat							Special Needs
	Marsh				Swamp			Open		woodland					
***In this column indicates area-or disturbance-sensitive species**	cattail	graminoid	low shrub	bog	tall shrub	coniferous	deciduous	grassland	scrubland	young deciduous	mixed	mature deciduous	young coniferous	mature coniferous	
Ermine											*		*	*	
Least Weasel*								*	*	*	*	*	*	*	
Long-tailed Weasel*								*	*	*	*		*		
Black-footed Ferret*								*							
Mink*	*	*	*		*										
Wolverine*														*	
Badger*								*	*	*					
Striped Skunk								*	*	*	*	*	*		
River Otter*					*	*	*								Rivers, creeks and ponds
Cougar*											*				Mountains and foothills
Canada Lynx*											*			*	
Bobcat*								*	*	*	*		*		
Wapiti*											*				
Mule Deer*						*	*	*	*	*	*				
White-tailed Deer		*	*	*	*	*	*	*	*	*	*	*	*		
Moose*											*				Lakes, bogs and streams
Caribou*											*			*	
Pronghorn*								*	*						
Bison*									*	*	*		*		
Mountain Goat*															Rocky terrain
Bighorn Sheep*															Rocky terrain

Appendix H

Significant Animal Species of Alberta

H. Significant Animal Species of Alberta

PART 1
SIGNIFICANT HERPTILE (REPTILE AND AMPHIBIAN) SPECIES OF ALBERTA

Species	Status	Habitat and Background
Wetlands		
Long-toed Salamander	Re[5]; SASR[2]; R[3]	Mountain woodlands; requires ponds for breeding
Grey Tiger Salamander	RFP[3]	Variety of habitats; near lakes
Great Plains Toad	Re[5]; PCAP[1]; SASR[2]; E[3]	Short-grass prairie; requires sloughs, ditches and flooded fields for breeding
Canadian Toad	Re[5]	Boreal and parkland habitats; dramatic decline in parkland regions.
Northern Leopard Frog	Re[5]; PCAP[1]; SASR[2]; T[3]	Meadowlands, fields; requires semi-permanent water for breeding; reasons for recent declines not understood
Plains Spadefoot Toad	B[5]; PCAP[1], T[3]	Shortgrass prairie; ditches, sloughs and flooded fields required for breeding
Boreal Toad	B[1]; PCAP[1]	Rocky Mountains and foothills
Spotted Frog	B[5]	Margins of streams, rivers, marshes and lakes; forages in adjcent woods and meadows.
Western Painted Turtle	B[1]; PCAP[1]; En[3]	Occurs only in Milk River drainage; permanent water bodies adjacent to sandy uplands
Uplands		
Short-horned Lizard	SASR[2]; T[3]	Bare, sandy ground and south-facing coulees in southeastern Alberta
Western Hognose Snake	SASR[2]; En[3]	Short-grass prairie
Prairie Rattlesnake	B[5]	Localized habitat; key habitats (winter dens) vulnerable

Legend:
RFP = Recommended for Protection
SASR = Species at Serious Risk
R = Rare
Re = Red List: species at risk: whose populations have declined, or believed to have declined, to non-viable levels, or show a rate of decrease indicating that they are at immediate risk of declining to non-viable levels in Alberta
B = Blue List: species which may be at risk: species which are particularly vulnerable because of non-cyclical declines in population or habitat or reductions in provincial distribution.
V = Vulnerable: species few in number or found only in very restricted areas and therefore, while not in immediate danger, could become so at any time.
T = Threatened: species likely to become endangered if the pressures from human or natural causes making them vulnerable are not reversed.
En = Endangered: species threatened with immediate extinction or extirpation because of human actions
Ex = Extinct
PCAP = Prairie Conservation Action Plan: listed species are those which are considered as species of concern due to population or habitat declines
[1] D.A. Westworth and Associates Ltd., 1993 (Appendix C)
[2] Alberta Environmental Protection, 1995 (Appendix C)
[3] Posey, 1992 (Appendix C)
[4] Allen, 1991 (Appendix C)
[5] Wildlife Management Division, 1996

PART 2
SIGNIFICANT BREEDING BIRD SPECIES OF ALBERTA

Species	Status	Breeding Habitat and background
Wetlands		
Whooping crane	En[1,2,3]; Re[5]; SASR[2]	Vast open marshes: declines due to hunting, egg-collecting, habitat destruction
Piping Plover	En[1,2,3]; Re[5]; SASR[2]	Sandy shores: recreational use of beaches threatens breeding habitat.
Eskimo Curlew	En[1], B[1]	Tundra; possibly extinct: unlikely to be affected by treatment wetland
Long-billed Curlew	B[5], T[1], R[1]; SASR[2]	Prairie : declines due to over-hunting and loss of grassland habitat
Cooper's Hawk	V[1], PCAP[1]	Dense, pure or mixed deciduous and coniferous forests: at risk because of habitat destruction, pesticides, past shooting
Short-eared Owl	B[5]	Grassland habitat: causes of population declines unknown
Great Gray Owl	V[1], PCAP[1]	Undisturbed boreal forest, usually near water: at risk because of unknown or declining numbers. Reasons for declines unknown
American White Pelican	B[1,3], PCAP[1]	Colonial breeder on treeless islands in large lakes, remote from human activity.
Bald Eagle	B[1], PCAP[1]	Tall trees near a large body of water remote from human disturbance: declines due to past shooting, habitat loss, pesticides
Osprey	B[1]	Tall nest structures next to large water body: past declnes due to shooting, pesticides; still monitored closely.
Caspian Tern	B[1]	Sparsely-vegetated isolated islands in large lakes; usually colonial: rare breeder in Alberta
Trumpeter Swan	B[5], En[1,2,3], PCAP[1]; SASR[2]	Shallow, isolated, marshy lakes: past declines due to hunting and habitat loss; focus of intense restoration efforts
American Avocet	PCAP[1]	Sparsely-vegetated islands near mudflats: colonial breeder: declining in northern part of its range but common elsewhere
Marbled Godwit	PCAP[1]	Borders of lakes or sloughs: in short native prairie: Declines probably due to habitat destruction
White-faced Ibis	PCAP[1]	Marshes of larger lakes: sensitive to marsh drainage, human disturbance, pesticides.
Willet	PCAP[1]	Common in grassland and parkland regions
Uplands		
Peregrine Falcon	Re[5], En[1,2,3], SASR[2]	Cliffs: unlikely to be affected by treatment wetland
Baird's Sparrow	SASR[2]	Tall, open grassland: declines due to habitat destruction; intolerant of heavy grazing
Burrowing Owl	Re[5], En[2,3]; SASR[2]	Level, open shortgrass areas with colonial rodents and nest burrows: declines due to habitat and prey species destruction
Ferruginous Hawk	B[5], En[2]; SASR[2]	On cliffs or tall structures in sparsely treed dry mixed prairie: declines due to encroachment of aspen, spread of agriculture; population recovering
Sage Grouse	B[5]	Restricted to sagebrush-grassland habitat, currently being degraded; population declining rapidly
Loggerhead Shrike	SASR[2]	Lightly wooded river valleys and coulees: reason for decline not understood
Mountain Plover	En[2]; SASR[2]	Large areas of short grasslands: declines due to large-scale habitat destruction
Upland Sandpiper	SASR[2]	Wide expanses of open, grassy uplands: declines due to loss of grassland habitat; trends unclear
Bay-breasted Warbler	B[5]	Declining, dependent on old-growth forest; intolerant of harvest
Black-throated Green Warbler	B[5]	Dependent on old-growth coniferous forest: intolerant of harvest

PART 2
SIGNIFICANT BREEDING BIRD SPECIES OF ALBERTA

Species	Status	Breeding Habitat and background
Sprague's Pipit	B[5]	Depends on grasslands; dramatic population declines
Cape May Warbler	B[5]	Depends on old-growth forest

Legend:
R = Rare
SASR = Species at Serious Risk
Re = Red List: species at risk: whose populations have declined, or believed to have declined, to non-viable levels, or show a rate of decrease indicating that they are at immediate risk of declining to non-viable levels in Alberta
B = Blue List: species which may be at risk: species which are particularly vulnerable because of non-cyclical declines in population or habitat or reductions in provincial distribution.
V = Vulnerable: species few in number or found only in very restricted areas and therefore, while not in immediate danger, could become so at any time.
T = Threatened: species likely to become endangered if the pressures from human or natural causes making them vulnerable are not reversed
En = Endangered: species threatened with immediate extinction or extirpation because of human actions
Ex = Extinct
PCAP = Prairie Conservation Action Plan: listed species are those which are considered as species of concern due to population or habitat declines
[1] D.A. Westworth and Associates Ltd., 1993 (Appendix C)
[2] Alberta Environmental Protection, 1995 (Appendix C)
[3] Posey, 1992 (Appendix C)
[4] Allen, 1991 (Appendix C)
[5] Wildlife Management Division, 1996 (Appendix C)

PART 3
SIGNIFICANT MAMMAL SPECIES OF ALBERTA

Species	Status	Habitat and Background
Wetlands		
Yellow-cheeked Vole	Re[1]; SASR[2]	Upland areas along rivers near stands of horsetails: found only along the Athabasca River; possibly extirpated.
Wandering Shrew	B[1]	Collected only at one site along a mountain stream in a coniferous forest
River Otter	B[1]	Large tracts of wooded or brushy habitat: sensitive to human disturbance and habitat fragmentation
Brown Lemming	B[1]	Shrub-sedge meadow in subalpine forest in northernmost portion of Rocky Mountains: limited in distribution
Uplands		
Swift Fox	Re[5], En[1,2,3]; SASR[2]	Open grasslands: formerly extirpated, re-introductions breeding in the wild. Sensitive to habitat fragmentation, decline in prey species
Wood Bison	Re[5], En[1,2,3]; SASR[2]	Sensitive to hunting, habitat destruction and fragmentation; entire Alberta population in captivity; disease concerns in northern Alberta
Woodland Caribou	B[5]	Extensive mature coniferous forests for cover and lichen production: sensitive to hunting, fire, logging, fragmentation
Grizzly Bear	B[5]	Threatened by loss of wilderness habitats
Ord's Kangaroo Rat	B[5]	Very localized, dependent on sand dunes
Red-tailed Chipmunk	B[5]	Population low, vulnerable to habitat loss
Wolverine	B[5]	Possibly only 1000

Legend:
R = Rare
SASR = Species at Serious Risk
Re = Red List: species at risk: whose populations have declined, or believed to have declined, to non-viable levels, or show a rate of decrease indicating that they are at immediate risk of declining to non-viable levels in Alberta
B = Blue List: species which may be at risk: species which are particularly vulnerable because of non-cyclical declines in population or habitat or reductions in provincial distribution.
V = Vulnerable: species few in number or found only in very restricted areas and therefore, while not in immediate danger, could become so at any time.
T = Threatened: species likely to become endangered if the pressures from human or natural causes making them vulnerable are not reversed
En = Endangered: species threatened with immediate extinction or extirpation because of human actions
Ex = Extinct
PCAP = Prairie Conservation Action Plan: listed species are those which are considered as species of concern due to population or habitat declines
[1] D.A. Westworth and Associates Ltd., 1993 (Appendix C)
[2] Alberta Environmental Protection, 1995 (Appendix C)
[3] Posey, 1992 (Appendix C)
[4] Allen, 1991 (Appendix C)
[5] Wildlife Management Division, 1996 (Appendix C)

PART 4
SIGNIFICANT FISH SPECIES OF ALBERTA

Species	Status	Habitat
Banff Longnose Dace	Ex? [3]	
Western Silvery Minnow	R [3], PCAP[1]	Clear rivers
Lake Sturgeon	En[3]	Lakes and large rivers with clean bottoms
Shortjaw Cisco	T[1]	Cooler depths of well-oxygenated lakes
Blackfin Cisco	T[1]	Cooler depths of well-oxygenated lakes
Shorthead Sculpin	T[1]	
Bull Trout	PCAP[1]	Cold lakes and streams
Walleye	At risk of loss or declining[6]	Large rivers

Legend:
R = Rare
Re = Red List: species at risk: whose populations have declined, or believed to have declined, to non-viable levels, or show a rate of decrease indicating that they are at immediate risk of declining to non-viable levels in Alberta
B = Blue List: species which may be at risk: species which are particularly vulnerable because of non-cyclical declines in population or habitat or reductions in provincial distribution.
V = Vulnerable: species few in number or found only in very restricted areas and therefore, while not in immediate danger, could become so at any time.
T = Threatened: species likely to become endangered if the pressures from human or natural causes making them vulnerable are not reversed
En = Endangered: species threatened with immediate extinction or extirpation because of human actions
Ex = Extinct
PCAP = Prairie Conservation Action Plan: listed species are those which are considered as species of concern due to population or habitat declines
[1] D.A. Westworth and Associates Ltd., 1993 (Appendix C)
[2] Alberta Environmental Protection, 1995 (Appendix C)
[3] Posey, 1992 (Appendix C)
[4] Allen, 1991 (Appendix C)
[5] Wildlife Management Branch, 1991 (Appendix C)
[6] Berry, 1995 (Appendix C)

Part 5

Sensitive species not currently believed to be at risk; but which may require special management to address concerns related to low natural populations, limited provincial distribution or demographic/life history features that make them vulnerable to human related changes to the environment particular biological needs (designated "Yellow" status by Wildlife Management Division, 1996, includes Yellow A and B).

Amphibians
Long-toed Salamander

Reptiles
Bull Snake
Plains Garter Snake
Red-sided Garter Snake
Wandering Garter Snake
Western Painted Turtle

Birds
American Arocet
American Bittern
American Dipper
American White Pelican
Baird's Sparrow
Bald Eagle
Barred Owl
Black Swift
Black Tern
Black-crowned Night-heron
Black-backed woodpecker
Black-necked Stilt
Black-and-white Warbler
Bobolink
Boreal Owl
Brewer's Sparrow
Broad-winged Hawk
Brown Creeper
Brown Thrasher
Canada Warbler
Caspian Tern
Chestnut-sided Warbler
Clarke's Crebe
Clarke's Nutcracker
Clay-coloured Sparrow
Cooper's Hawk
Double-crested Cormorant
Forster's Tern
Golden Eagle
Golden-crowned Sparrow
Grasshopper Sparrow
Great Blue Heron
Great-crested Flycatcher
Great Gray Owl
Harlequin Duck
Horned Grebe
Herring Gull
Lark Sparrow
Lesser Yellowlegs
Loggerhead Shrike

Birds (cont'd)
Marsh Wren
Mountain Plover
Mourning Warbler
Northern Goshawk
Northern Harrier
Osprey
Pied-Billed Grebe
Pileated Woodpecker
Prairie Falcon
Red-necked Grebe
Ring-necked Pheasant
Rock Wren
Sandhill Crane
Sedge Wren
Sharp-tailed Grouse
Swainson's Hawk
Townsend's Warbler
Turkey Vulture
Upland Sandpiper
Western Flycatcher
Western Grebe
Western Meadowlark
Western Tanager
Winter wren
White-faced Ibis
Willet
Winter Wren
Yellow-breasted Chat

Mammals
Badger
Bobcat
Canada Lynx
Cougar
Fisher
Hoary Marmot
Long-tailed Weasel
Mountain Goat
Northern Flying Squirrel
Northern Grasshopper Mouse
Nuttall's Cottontail
Pronghorn (Antelope)
Richardson's Ground Squirrel
Thirteen-lined Ground Squirrel
Wandering Shrew
Water Vole
Western Harvest Mouse
Western Small-footed Bat

APPENDIX I

ANNOTATED BIBLIOGRAPHY FOR WETLAND EVALUATIONS

I. Annotated Bibliography for Wetland Evaluation

A. General

Alberta Environmental Protection. 1995. Alberta's state of the environment: a comprehensive report. Publication I/583, Alberta Environmental Protection.

Alberta Environmental Protection. 1993.

- Summarizes the services provided by the Department of Environmental Protection.

Alberta Water Resources Commission. 1993. Beyond Prairie Potholes: a draft policy for managing Alberta's peatlands and non-settled area wetlands: for discussion purposes. Alberta Water Resources Commission, Edmonton.

Alberta Water Resources Commission. 1993. Wetland Management in the settled area of Alberta: an interim policy. Alberta Water Resources Commission, Edmonton.

Alberta Water Resources Commission. 1993. Alberta's peatlands and non-settled area wetlands: a background report. Alberta Water Resources Commission, Edmonton.

Alberta Water Resources Commission. 1991. Wetland management in the settled area of Alberta: a summary of public comments. Alberta Water Resources Commission, Edmonton.

Alberta Water Resources Commission. 1990. Wetland management in the settled area of Alberta: a background for policy development. Alberta Water Resources Commission, Edmonton.

Alberta Water Resources Commission. 1990. Wetlands: values and options: a draft policy for the management of wetlands in the settled area of Alberta. Alberta Water Resources Commission, Edmonton.

Bramm, S. 1992. Protecting ecosystems in Alberta: a survey of government mechanisms. Environmental Council of Alberta.

Bramm, S. 1992. Protecting ecosystems in Alberta: a survey of government mechanisms. Environmental Council of Alberta, Edmonton, Alberta.

- Summarizes Long Range Integrated Resource Planning Program for Alberta.

Coupland, R.T. 1987. Endangered prairie habitats: the mixed prairie. In Holroyd, G.L., P.H.R. Stepney, G.C. Trottier, W.B. McGillivray, D.M. Ealey and K. E. Eberhart. 1987. Endangered species in the prairie provinces. Provincial Museum of Alberta Natural History Occasional Paper No. 9.

Indicates the decline of woodland on prairie in Alberta and Saskatchewan.

D.A. Westworth and Associates Ltd. 1993. Functions and values of Alberta's wetlands. Report for Wetlands Management Steering Committee. North Petroleum Plaza, Edmonton, Alberta.

- Summarizes function and values of wetlands, including social, economic, hydrologic habitat, heritage and water quality improvement functions.

D.A. Westworth & Associates Ltd. 1990. Significant natural features of the eastern boreal forest region of Alberta. Tech. Rept. for Alberta Forestry, Lands and Wildlife.

- details locations of regionally, provincially and nationally significant significant features; significance based on analysis of hydrology, landform, rare flora and fauna, fisheries, wildlife corridors, wintering areas for moose, habitat for furbearers, and waterfowl staging.

Dyson, I.W. 1993. Implementing the Prairie Conservation Action Plan in Albert 1989 to 1991 - two years of progress. In Holroyd et al. 1993 (above).

- This paper describes the role of the Prairie Conservation Coordinating Committee and provides examples of implementation of Prairie Conservation Action Plan goals.

Dyson, I.W. 1993. Public land management approaches for conserving native prairie environments - some Alberta examples. In Holroyd et al. 1993.

- The need to work cooperatively with landowners and all the players in the prairie landscape mosaic is imperative.

Environmental Council of Alberta. 1995. Social, economic and environmental trends affecting Alberta's future. Environmental Council of Alberta working document, Edmonton.

Government of Alberta. 1992. Special places 2000: Alberta's natural heritage. Completing Alberta's endangered spaces network (draft). Alberta Tourism, Parks and Recreation, Forestry, Lands and Wildlife.

Holroyd, G., G. Burns and H.C. Smith. 1989. Endangered species and prairie conservation workshop: proceedings presented by the Saskatchewan Natural History Society. Provincial Museum of Alberta Occasional Paper.

Holroyd, G.L., G. Burns and H.C. Smith. 1991. Proceedings of the second endangered species and prairie conservation workshop. Provincial Museum of Alberta Natural History Occasional paper No. 15.

- This volume summarizes papers discussing legislation, habitat conservation, etc. in the prairie provinces.

Holroyd, G.L., H.L. Dickson, M.Regnier and H.C. Smith. 1993. Proceedings of the third prairie conservation and endangered species workshop. Provincial Museum of Alberta Occasional Paper No. 19.

Nietfield, M., J. Wilk, K. Woolnough and B. Hoskin. 1985. Wildlife habitat requirement summaries for selected wildlife species in Alberta. Alberta Energy and Natural Resources (ENR Technical Report T/73), Fish and Wildlife Division, Edmonton.

Pachal, D. 1992. Wild Alberta. Environmental Council of Alberta, Edmonton, Alberta.

- Tabulates significant natural areas proposed for protection, and rationale for protection.

Pachal, D. 1992. Wild Alberta. Environmental Council of Alberta.

- Lists and maps significant natural areas proposed for protection, provides rationale for them.

Posey, M. 1992. Saving the strands of life: Alberta's biodiversity. Environmental Council of Alberta, Edmonton.

Strong, W.L., B.K. Calverley, A.J. Richard, and G.R, Stewart. 1993. Characterization of wetlands in the settled areas of Alberta. Rept. for Wetlands Management Steering Committee, Edmonton, Alberta.

- Summarizes wetland characteristics of the 34 ecodistricts that occur within the Settled Area of Alberta; including various measures of vulnerability; such as climatic vulnerability, arable land rating, number of wetlands per km2, average wetland size, degree of water permanency, number of waterfowl per km2, percent developed land and number of drainage projects.

Usher, R. 1990. Alberta's wetlands: water in the bank. Environmental Council of Alberta.

Summarizes benefits and functions of wetlands.

Usher, R. and J. Scarth. 1990. Alberta's wetlands: water in the bank. Environmental Council of Alberta, Edmonton, Alberta.

Wildlife Management Branch. 1991. The status of Alberta Wildlife. Rept. for Alberta Forestry, Lands and Wildlife Fish and Wildlife Division.

- Assigns status to reptiles, amphibians, birds and mammals of Alberta. Summarizes habitat parameters and background in species designated red, yellow and blue; the three highest categories of significance.

Wildlife Management Branch. 1991. The staut of Alberta Wiildlife. Alberta Forestry, Lands and Wildlife, Fish and Wildlife, Wildlife Management Branch, Edmonton.

- Divides amphibians, reptiles, birds, and mammals into four status categories according to the degree of risk attached to their persistence.

B. Plants and Plant Communities

Achuff, P.L. 1987. Rare vascular plants in the Rocky Mountains of Alberta. In: Holroyd et al. 1987 (above).

- Shows distribution of rare plants within the three montane ecoregions of Alberta.

Alberta Energy, Forestry, Lands and Wildlife. 1992. Alberta plants and fungi: a master species list and species list group checklists. General Services Division, Editorial Services.

Allen, L. 1991. Status of plant conservation in Alberta. In: Holroyd et al. 1991 (above).

- Areas known to have a concentration of species on the rare plant list include the Cordillera, the Canadian Shield, the southern grasslands, and a diverse area in the southwest corner of the province where several natural regions converge.

Brown, L.P. 1993. Holistic stewardship of prairie fragments. In: Holroyd et al. 1993 (see section A).

- Discusses rationale for preserving small patches of prairie in order to conserve biodiversity.

Griffin, D. 1987. Provincial perspectives on public lands-Alberta. In: Holroyd et al. 1987. (above).

Morgan, J.P. 1993. Restoring native prairie ecosystems. In Holroyd et al. 1993 (above).

Moss, E.H. 1983. Flora of Alberta. Second Edition revised by J.G. Packer. University of Toronto Press, Toronto.

Moss, E.H. 1983. Flora of Alberta. Second Edition, revised by J.G. Packer. University of Toronto Press, Toronto.

Packer, J.G. and C.E. Bradley. 1984. A checklist of the rare vascular plants of Alberta. Provincial Museum of Alberta Occasional Paper No.5.

Lists the 360 species of plants considered rare in Alberta.

Purdy, B.G. and S.E. MacDonald. 1992. Status report on the sand stitchwort *Stellaria arenicola*. Committee on the Status of Endangered Wildlife in Canada.

- Restricted endemic of Athabasca sand dunes, but no designation required.

Smith, B. 1993. Status report on the Kananaskis Whitlow-cress *Draba kananaskis*. Committee of the Status of Endangered Wildlife in Canada, Ottwa.

Smith, B. and C. Bradley. 1992. Status report on the smooth goosefoot (*Chenopodium subglabrum*). Committee on the Status of Endangered Wildlife in Canada, Ottawa.

- Few sites, small populations; threatened status recommended

Smith, B. and C. Bradley. 1992. Status report on the sand verbena (*Abronia micrantha*). Committee on the Status of Endangered Wildlife in Canada, Ottawa.

- Habitat threatened: Threatened status recommended

Smith, B. and C. Bradley. 1992. Status report on the western spiderwort. *Tradescantia occidentalis*. Committee on the Status of Endangered Wildlife in Canada, Ottwa.

- Restricted habitat threatened by invasive weeds and exploration for oil: endangered status recommended

Smith, B. 1993. Status report on the little barley (*Hordeum pusillum*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

- Insufficient information to award status

Wallis, C.L. 1987. Critical, threatened and endangered habitats in Alberta. In: Holroyd et al. (above).

- lists significant landscape types in mixed grassland, northern fescue grassland, foothills grassland, central parkland and foothills parkland. Notes that 66% of the mixed grassland and 95% of upland central parkland and northern fescue grassland has been lost.

C. Fisheries

Berry, D. 1995. Alberta's Walleye management and recovery plan. Alberta Environmental Protection, Natural Resources Service, Fisheries Management Division.

Roberts, W. 1987. The bull trout-endangered in Alberta. In: Holroyd et al. 1987 (above).

Excessive angler harvest is the major factor in decline of bull trout.

Roberts, W. 1991. The bull trout: vanishing from the prairie and parkland of western Alberta. In: Holroyd et al 1991 (above).

D. Herpetiles

Butler, J.R., and W. Roberts. 1987. Considerations in the protection and conservation of amphibians and reptiles in Alberta.

- Of eighteen species of amphibians and reptiles, seven species (39%) are uncommon enough to be recognized as potentially threatened. The majority of these species and populations under concern are associated with prairie environments.

Powell, G.L. and A.P. Russel. 1993. The range and status of the eastern short-horned lizard in the Canadian prairies. In Holroyd et. al. 1993 (above).

- Summarizes distribution and status of these species, recommends strategies for protection.

Roberts, W. 1987. The northern leopard frog-endangered in Alberta. In: Holroyd et al. 1987 (above).

- Discusses the decline of leopard frogs in Alberta, but suggests the causes are unclear.

E. Birds

Cadman, M.D. 1993. Status report on the Northern Harrier (Circus cyaneus) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

Canadian Burrowing Owl Recovery Team. 1995. National recovery plan for the Burrowing Owl. RENEW Canada Report No. 13.

Cannings, R.J. 1992. Status report on the Sage Thrasher *Oreoscoptes montanus* in Canada. Committee on the Stauts of Endangered Wildlife in Canada, Ottawa.

- Small population in restricted range in threatened habitat: endangered status recommended.

Colwell, M.A. 1991. Effects of fluctuating wetland conditions on prairie shorebirds. In : Holroyd et al. 1991 (above).

- Shorebirds are adapted to a narrow range of water fluctuations; prey species and nesting habitat may decline if water levels vary outside normal perturbations. Habitat and underlying food resources for prairie shorebirds are much less predictable, owing largely to seasonal and annual variations in climate.

De Smet, K.D. 1992. Status report on the long-billed Curlew *Numenius americanus* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

- undisturbed short and mixedpgrass prairie: recommended status vulnerable

Dickson, H.L. and A. R. Smith. 1991. The western hemisphere shorebird reserve network and the prairie shorebird program. In: Holroyd et al. 1991 (above).

Lists proposed regional shorebird reserves in the prairie provinces.

Erickson, G. 1987. Status of Burrowing Owls in Alberta. In: Holroyd et al. 1987. (aboove)

Discussion of population and status of Burrowing Owls in Alberta.

Goossen, J.P., et al. 1993. Canadian Baird's Sparrow recovery plan. RENEW Canada Report No.3., 95-01621

Goossen, J.P. 1991. Prairie Piping Power conservation: Annaul Report 1990. Canadian Wildlife Service, Edmonton.

James, P.C. 1993. Habitat fragmentation and Burrowing Owls in Saskatchewan. In Holroyd et al. 1993 (above)

- Larger pastures contain more breeding pairs and they persist longer

Johns, B.W. 1993. The effects of habitat patch size on avian communities in aspen parklands. In Holroyd et al. 1993 (above)

- This paper discusses the increase in species richness and abundance with increased habitat patch size.

Kuyt, E. 1987. Whooping Crane. In: Holroyd et al. (above).

Discusses numbers and management of Whooping Cranes.

Moore, D.A. 1987. The Ferruginous Hawk in Alberta. In: Holroyd et al. 1987 (above).

- Maintenance of undisturbed grasslands appears essential for the survival of this species.

Moyles, D. 1987. The Greater Prairie Chicken in Alberta. In: Holroyd et al. (above).

Lists possible reasons for the extirpation of this species.

- The main requirement for reestablishment would be a minimum of 2000 to 4000 ha of grasslands.

Nudds, T.D. and R.G. Clark. 1993. Landscape ecology, adaptive resource management and the North American Waterfowl Management Plan (NAWMP). In Holroyd et al (above)

- This paper presents an experimental protocol which may contribute to resolving unanswered questions about the efficacy of intensive versus extensive management

Poston, B., D.M. Ealey, P.S. Taylor, and G.B. McKeating. 1990. Priority migratory bird habitats of Canada's Prairie Provinces. Habitat Conservation Section, Canadian Wildlife Service, Western and Northern Region, Environment Canada, Edmonton, Alberta

Lists migratory bird habitat in Alberta, Saskatchewan and Manitoba

Schmutz, J.R. 1993. Grassland requirements by Ferruginous Hawks. In Holroyd et al. 1993 (above)

- Ferruginous hawks are generally common where a ranching land use prevails

Schmutz, J.K. 1991. Population dynamics of Ferruginous Hawks in Alberta. In: Holroyd et al 1991 (above).

Schmutz, J.K. 1987. Factors limiting the size of the breeding population of Ferruginous Hawks. In: Holroyd et al. (above).

- Review of previously suggested reasons for the decline in Ferruginous Hawks.

Semenchuk, G.P. 1992. The atlas of breeding birds of Alberta. Federation of Alberta Naturalists, P.O. Box 1472, Edmonton, Alberta. T5J 2N5

- The most comprehensive surveys to date of Alberta's avifauna.

Shandruk, L. 1987. A review of habitat requirements and management priorities for the Canadian breeding population of Trumpeter Swans. In: Holroyd et al. (above).

Smith, W.W. 1987. The Baird's Sparrow in Alberta. In: Holroyd et al. (above).

- Discusses distribution and habitat of this threatened /endangered species in Alberta : the species is considerred to be significant because of its requirement for continuous tracts of fescue grassland; one of the most endangered ecosystems in North America.

Smith, W.W. 1991. The Loggerhead Shrike in Alberta. In: Holroyd et al. 1991 (above).

Loggerhead Shrikes have drastically declined in Alberta.

Stepney, P.H.R. 1987. Management considerations for the American White Pelican in Alberta. In: Holroyd et al. (above).

- Documents characteristics of nest sites in Alberta, lists past and suggested actions for management.

Updated status report on the Short-eared Owl (Asio flammeus) in Canada.

Wershler, C.R. 1987. The piping plover in Alberta. In: Holroyd et al. 1987. (above).

Discusses habitat, population,limiting factors, etc.

Wershler, C.R. 1987. The Mountain Plover in Canada. In: Holroyd et al. 1987 (above).

- Discusses habitat, population, limiting factors, etc. of this endangered species; an example of a species with requirements for grassland-interior habitat.

Wershler, C., W.W. Smith, and C. Wallis. 1991. Status of the Bairds Sparrow in Alberta-1987/1988 update with notes on other grassland sparrows and Sprague's Pipit. In: Holroyd et al. 1991 (above).

Wershler, C. 1991. A management strategy for Mountain Plovers in Alberta. In: Holroyd et al 1991 (above).

- Discusses relationship of grazing pressure to distribution of grassland sparrows.

F. Mammals

Barclay, R.M.R. 1993. The biology of prairie bats. In Holroyd et al. 1993 (above).

- Summarizes biology and habitat, makes recommendations for further study.

Barrett, M.W. 1987. History and management of the pronghorn in Alberta. In: Holroyd et al. 1987 (above).

Discussion of management issues affecting pronghorn.

Culbert, D. 1987. Legal status of endangered species in Alberta. In: Holroyd et al. 1987 (above).

Dubois, J.1987. Small mammals. In: Holroyd et al. 1987 (above).

Discusses mammal species of concern in the prairie provinces.

Edmonds, E.J. 1987. Current status and proposed management plans for woodland caribou in Alberta. In: Holroyd et al. 1987 (above).

- Four major management problems require special consideration and resolution: the destruction and alteration of Caribou habitat, the increased access to caribou ranges resulting from industrial roads, the continued loss of caribou to hunting despite closed seasons, and the high levels of wolf predation in west central Alberta.

Johnson, C., McFetridge, R.J., and W. Runge. 1993. Status report on the prairie long-tailed weasel (*Mustela frenata longicauda*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.

- population appears to be secure and stable in Alberta: no designation required

Neitfield, M., J. Wilk, K. Woolnough and B. Hoskin. 1985. Wildlife habitat requirement summaries for selected wildlife species in Alberta. ENR Tech. Rep. T/73; Alberta Energy and Natural Resources, Fish and Wildlife Division.

- Provides summaries of key habitat requirements for mule deer, white-tailed deer, moose, elk, woodland and mountain caribou, pronghorn antelope, rocky mountain bighorn sheep, mountain goat, grizzly bear, beaver, river otter, marten, sharp-tailed Grouse, Ring-necked Pheasant, Sage Grouse, resident breeding dabbling ducks, breeding Canada Geese, and moulting, staging and migrant waterfowl.

Reynolds, H.W. 1987. The Canadian Wildlife Service program to restore wood bison. In: Holroyd et al. 1987 (above).

Smith, H.C. 1993. Alberta Mammals: an atlas and guide. Provincial Museum of Alberta, Edmonton, Alberta.

Appendix J
Methods to Design and Construct Wetland Systems

J. Methods to Design and Construct Wetland Systems

Overview of Design Criteria

Wetland design criteria requires careful consideration of wetland type, configuration, size, water source, soils, and vegetation. Wetland design methods and criteria are continually being improved. The wetland designer should review the references included in this manual and obtain reviews from senior wetland design engineers of all design and construction plans prior to proceeding with construction.

Type

The type of constructed wetland system desired may depend upon the feasibility of using natural wetlands for treatment, treatment performance requirements, estimated cost, and availability of required land area, among other site-specific conditions. Surface flow wetlands and subsurface flow wetlands each have distinct advantages but subsurface flow wetlands may be desired where land is limited or too expensive.

Area

Because wetland construction is inherently land intensive, the total area required for wetland construction may be the single most important parameter for wetland feasibility, particularly in urban areas where land is limited and expensive. Sizing criteria described below should be used during conceptual and final designs to assist in determining project feasibility.

Constructed Wetlands

Natural and constructed wetlands may be used for removal of pollutants from domestic, industrial and non-point source wastewater. The area required for a treatment wetland to meet the specific design objectives depends on a wide range of factors. Total area required for natural and constructed wetland treatment systems will vary as a function of the volume and quality of influent to be treated, desired wetland effluent quality, and allowable hydraulic loading rate.

Total wetland area should be based upon published or empirical pollutant mass removal data for the pollutant parameter of concern with the lowest pollutant removal efficiency. Wetland area requirements to achieve target pollutant concentrations in the effluent are available in Kadlec and Knight (1996), and WPCF (1990).

Natural Treatment Wetland Systems

Conservative recommended hydraulic loading rates range from 0.2 cm/d (50 ha/1,000 m^3/d) if pretreatment is secondary without nitrification to 0.5 cm/d (20 ha/1,000 m^3/d) for nitrified secondary effluent. If concentrations of BOD_5, TSS, phosphorous, and other constituents are reduced in pretreatment, the recommended conservative hydraulic loading rate is 2.5 cm/d (4 ha/1,000 m^3/d) (Kadlec and Knight, 1996).

Constructed Surface Flow (SF) Wetland

The typical range of hydraulic loading rates is from 1.5 to 6.5 cm/d (6.7-1.5 ha/1,000 m^3/d) with a central tendency of 3 cm/d (3.3 ha/1,000 m^3/d) (Kadlec and Knight, 1996).

Constructed Subsurface Flow (SSF) Wetland

The typical range of hydraulic loading rates is from 8 to 30 cm/d (1.3-0.3 ha/1,000 m^3/d (Kadlec and Knight, 1996).

Stormwater Wetland

MOEE (1992) recommended that stormwater wetland area be determined as 5 percent of the watershed area. Schueler (1992) indicated that a smaller wetland area of 1 percent of the total watershed area was considered acceptable for wetlands with deep zones and longer hydraulic residence times. Kadlec and Knight (1996) note that the central tendencies for stormwater wetlands are similar to those of point source SF wetlands.

Configuration

Constructed Wetlands

Constructed wetlands are typically designed as single- or multiple-cell compartments in series or parallel to allow redistribution of flows, maintenance of plant communities, and flexibility of operation (WPCF, 1990). Multiple input points or an inflow deep zone the full width of the treatment wetland allow for even distribution of effluent to the wetland. The economic minimum aspect (length:width) ratio of 2:1, a gradual wetland slope on the order of 0.05 percent, and deep zones at least 1 m in depth oriented perpendicular to the wetland flow provide even distribution of the wetland flow (Kadlec and Knight, 1996).

Water Source and Management

Predictability of water source availability, quality, and management is important to maintain design hydroperiods and to attain pollutant removal performance criteria in treatment wetlands. Water depth, hydraulic residence time, and inlet distribution and outlet structures are critically important engineering considerations.

Shallow wetland water depths maintain dissolved oxygen concentrations sufficient to support nitrification. For optimum performance, experience suggests that the average water depth for an SF wetland is 30 cm with typical water depths ranging from 0.15 to 0.45 cm (Kadlec and Knight, 1996). SSF wetland water levels are designed to be below the ground surface with a typical bed depth of less than 0.6 m and water depths ranging from 0.3 to 0.6 cm (Kadlec and Knight, 1996). Natural wetland water depths may vary over a wider range than SF wetlands, but are most effective if they do not exceed 50 cm.

The minimum hydraulic retention time for SF treatment wetlands is 7 to 10 days, for SSF wetlands 2 to 4 days, and 14 to 20 days for natural treatment wetlands are typical (Kadlec and Knight, 1996).

Wetland influent should be provided a minimum of primary treatment in SF and SSF wetlands (WPCF, 1990), and secondary with nitrification and phosphorus reduction in natural wetland treatment systems.

Water distribution and collection structures should be simple to maintain, operate, and replace. Pipes should be slightly oversized. Trash racks or other suitable barriers should be erected upstream of the distribution system to prevent clogging.

Receiving Water

The point of discharge from the treatment wetland to the receiving water must be identified. Effluent discharge criteria will typically be established based on the receiving water quality.

Soils

Soils should be suited to support wetland vegetation and to support the desired hydrology of the wetland. Soils for constructed wetlands should include salvaged wetland or upland topsoil in order to facilitate the establishment of wetland vegetation. Topsoil use in constructed wetlands should be considered as an option, but is not necessary as long as the exposed soils to a depth of 30 cm are capable of supporting the planted vegetation. Berms should be constructed from stable materials and protected by erosion control materials and methods.

Vegetation

Wetland vegetation should be selected for its tolerance of inundation and oxygen-poor, reduced environments. Desirable characteristics include tolerance of prolonged inundation, low oxygen concentrations in the water and soils, and rapid dense growth to shade surface waters and reduce algal production. Planting stock originating from the project region will increase survival potential.

Planting centres may range from 1 to 2 m for constructed wetlands where more than 60% coverage is required in the first year of operation. Natural regrowth can be considered if the treatment wetland regulatory requirements allow for two to three seasons for vegetation establishment. Vegetative diversity in the wetlands can be encouraged through the use of topsoil as mulch where feasible, and additional species plantings,. However, treatment wetlands often become dense monocultures due to the high nutrient loadings and the more robust species, typically cattails, phragmites, and bulrushes, gain dominance.

Litter

Establishment of the litter layer may take from 1 year to more than 5 years. Improved removal efficiencies will likely be realized if imported litter, such as straw, is placed in the treatment wetland during construction of the system (Kadlec and Knight, 1996).

Feasibility Analysis and Design

The technical, regulatory and economic feasibility of a wetland construction project should be thoroughly evaluated prior to proceeding to final design and construction. It is important that the Owner understand that wetland technology is still in a developing phase, and that it is not possible to predict wetland performance with high precision. It is equally important that the Designer identify and take into consideration existing and known potential constraints to successful wetland construction and operation in order to provide reasonable assurance that

project objectives will be met. The following section outlines the basic stages and information needs of a wetland construction feasibility analysis. It is assumed that the goals and objectives of the project have been clearly identified and agreed to by the Owner, designer, and concerned regulatory staff, if applicable, as described earlier.

Site Selection

Selection of an appropriate location for wetland construction should be based upon an analysis of identified alternative locations and the extent to which they satisfy stated siting requirements, or criteria.

Site Selection Criteria

The successful location of a wetland construction project will balance the stated goals and objectives of the project with site-specific constraints. Criteria for locating a wetland will vary depending upon whether a wetland is being constructed to replace or restore lost ecological functions or enhance existing wetland functions, or whether a wetland is being constructed or enhanced to provide a new ecological function, as in a constructed or natural wetland treatment system.

Possible wetland site selection criteria may include the following:

- Proximity to desired location
- Availability of sufficient contiguous area
- Availability of suitable long-term wetland water source
- Favourable site hydrogeology
- Acceptable site geotechnical constraints
- Acceptable receiving stream and discharge conditions
- Presence of existing or potential limiting land use, natural wetlands, protected species, historical or archaeological resources on or adjacent to site
- Potential ease and cost of acquisition of ownership rights, easement, or other controlling interest
- Ease of access for construction and maintenance
- Availability of sufficient construction materials and labour resources

Proximity

This criterion will vary depending upon the type of wetland to be constructed. Wetlands designed to mitigate for total or partial loss of function may need to be constructed in the vicinity of the original wetland ("onsite" vs. "offsite"). Wetlands designed for stormwater treatment may need to be located at an appropriate topographic elevation in order to maximize gravity flow. Natural and constructed wetland treatment systems may need to be designed on or adjacent to the location of the pollution source in order to minimize land and pumping costs, and to control or limit public access.

Area

Total area requirements will vary with wetland goal, but in general, sufficient contiguous area should be available to allow the wetland to be constructed at one location to minimize construction, operation and maintenance costs. Preliminary estimates of the required area may be determined for the Site Selection Phase as described below under subsection "Conceptual Design".

Wetland Water Source

Treatment wetlands viability will be determined by the continued availability of wastewater effluent.

Hydrogeology

Site hydrogeology should be favourable for wetland construction. Excessively drained soils may not be suitable for wetland construction without the installation of an aquitard of clay or other materials of low hydraulic conductivity. Shallow depths to the surface of bedrock may also constrain wetland excavation.

Geotechnical Constraints

Wetland berm and substrate materials should be suitable for wetland construction and not lead to excessive erosion, sediment loss, or potential for failure under normal design extremes.

Limiting Land Uses and Other Siting Constraints

Human land use may constrain the suitability of a wetland construction location. Care should be taken to locate the wetland in areas with compatible zoning and other land uses in full recognition of the wetland design goals. The presence of natural wetlands, protected species habitats, and historical or archaeological resources on or adjacent to site may pose additional significant design constraints.

Ownership and Land Cost

Sites not currently under the ownership of the project owner will need to be assessed for ease of acquisition of ownership rights, easement, or other controlling interest. Since wetlands are land-intensive, land costs can significantly affect the total project cost.

Access

Each site should be evaluated for existing and potential ease of access for construction and future maintenance. Local land use regulations should be consulted to identify possible constraints to construction and maintenance traffic.

Materials

Availability of sufficient construction materials and labor resources should be evaluated within a regional context in order to minimize project cost and to maintain standards of quality for materials. The availability of skilled contractors, plant nurseries, and acceptable wetland construction materials should be assessed.

Data Collection

Sufficient data should be collected from each proposed construction site(s) to respond to the information needs of site-selection criteria, and to evaluate the potential for successful wetland permitting, construction and operation. Task 1 of this manual provides a checklist of information categories that will provide useful information for site selection, wetland design, and construction.

Site Selection

The site selection process should result in the selection of a location that provides the greatest probability that the wetland will cost-effectively achieve the intended design goals. Costs should include long-term operations and maintenance costs as well as initial land and construction costs.

Constructed Wetlands

The site selection process for constructed wetlands should emphasize identification and selection of a location that provides the greatest potential for performance towards achieving water quality improvement goals at the lowest cost of initial construction and long-term operation and maintenance. Selection of a suitable site for construction of a natural wetland treatment system will be strongly limited by the type and location of existing site wetlands.

Conceptual Design

It is important to note that successful wetland design is an iterative process that requires the technical input of biologists, engineers, construction contractors, resource regulatory staff, and the project Owners. A conceptual design should be prepared during the site selection process with available information in order to achieve the greatest realism in site selection. Key conceptual design elements include an approximate determination of wetland area, hydrologic requirements, ability to meet performance objectives, and cost of land and construction. These are discussed below by wetland type.

Area

Constructed Wetlands. Conceptual area requirements for natural and constructed wetland treatment systems should be conservatively determined as a function of hydraulic loading rate, pollutant loading rate, and performance objectives from published or experimentally-determined design criteria.

Types of information that will be needed to determine this criterion for the Conceptual Design Phase include the average influent water quality and flow rate, effluent water quality objectives and flow limitations, and receiving water quality and hydraulic capacity. Results of more detailed pollutant mass balances are required during the Final Design Phase to determine which pollutant will require the most area to achieve the wetland water quality objectives.

Hydrology

Constructed Wetlands. Most inflow to natural or constructed wetland treatment systems is predominantly treated wastewater, and water balances may not need to be calculated unless site soil permeability is potentially great enough for infiltration to be a significant hydrologic output from the wetland, or groundwater quality concern. A reliable and controllable hydraulic loading rate is the critical conceptual hydrologic design criterion for constructed wetlands.

Wetland Performance Objectives

Constructed Wetlands

Most natural or constructed wetland treatment systems will be designed to remove as much of a particular nutrient or suite of pollutants from wastewater as possible. Performance objectives in the form of mass removal rates should be established early in the Conceptual Design process to guide wetland sizing and configuration.

Cost Estimates

Conceptual estimates should be prepared for land costs based upon local real estate appraisals (if necessary), earthwork costs based upon approximate cut and fill volumes, planting costs based upon the product of an average plant cost determined from local nursery operators and the total estimated wetland area, culverts and pipes as needed, and long-term operations and maintenance costs.

Regulatory Feasibility and Permitting

Regulatory Feasibility

Regulatory Jurisdiction Determination

A master list of regulatory agency jurisdictions should be prepared, and specific information needs and design constraints identified.

Meeting

Meetings should be held with regulatory agency staff prior to permit submittal to confirm jurisdiction and permit information requirements. Return correspondence should be requested that verifies topics covered and conclusions drawn from each meeting.

Fatal Flaw Analysis

Fatal flaws in the wetland design or construction possibly resulting from regulatory restrictions should be identified through meetings with regulatory agency staff.

Permitting Requirements

Provincial and municipal constraints and requirements on wetland construction should be thoroughly investigated prior to beginning final design.

Final Design

Final design should essentially be a much more detailed presentation of the accepted conceptual design, in conformance with such comprehensive guidance as Kadlec and Knight (1996) and WPCF (1990). Detail on earthwork calculations, hydraulic characteristics, slopes, depths, and possible site constraints should be developed into a detailed construction package. Emphasis on detail should be placed on hydraulic structures and overall simplification of operation and maintenance requirements. Regulatory confirmation of design details should be sought prior to completion of the final design. A senior review by a qualified treatment wetland designer should be conducted of the complete design.

Construction Management and Monitoring

Construction Plans and Specifications

Wetland construction plans and specifications should be sufficiently detailed for bidding purposes, engineering and biological review, and verification of "as-built".

General

Wetland construction plans should include a table of contents, a detailed location map, a sheet key index, and a table of quantities. Individual sheets should include a compass arrow, scale bar, date of preparation, and a record of reviewers and revision dates.

Aerial Photography

If available, construction plans should include current aerial photographs at a scale sufficient to completely show the outline of the project work area on one or more sheets. Locations of key landmarks, water bodies and drainage pattern, wetlands and other restricted or protected areas (i.e. endangered or threatened species) should be indicated. Larger scale aerial photographs may be used as a background for the detailed plan set if interpretive clarity is not sacrificed.

Scale

A scale of 1 cm = 10 m or larger (i.e. 1 cm = 5 m) is recommended.

Topography

Wetland construction plans should be overlaid on a topographic map of existing site elevation contours. A 0.25 m contour interval is recommended as a minimum contour interval. Benchmark location and elevations should be clearly indicated.

Geotechnical Information

Locations of test borings and soil pits should be identified within the plan set so that they may be relocated, if desired. Soil profile illustrations should be identified and presented within the plan set and should include information on soil chroma profile elevations and observed water elevations.

Jurisdictional Wetland Boundaries

Jurisdictional wetland boundaries should be clearly and accurately identified on the site topographic map as negotiated with the regulatory agencies.

Hydrology

Plans should indicate existing and expected water levels, identify adjacent water bodies and to establish major surface drainage patterns at the construction site. All elevations should be made relative to National Geodetic Vertical Datum (NGVD), or an elevation conversion should be supplied. Site hydrological data should include seasonal high and average water elevations determined from vegetative indicators, soil indicators, or hydrological monitoring data for existing wetlands, if any, and at adjacent upland sites. Sufficient information should be developed to determine seasonal elevations of receiving waters. If necessary and feasible, provision should be made on a site-specific basis to divert water temporarily to the wetland and constructing temporary or permanent structures to provide inundation.

Planting Specifications

Construction plans should indicate zones or areas to be planted. A planting list should be prepared for each wetland zone that includes quantities, elevation ranges, and acceptable conditions. Special considerations or requirements should be noted and described in sufficient detail. These may include fertilizer specifications, pre-planting conditioning, geographic

constraints on plant sources, performance and irrigation requirements. Plants should be planted at intervals sufficiently dense to assure rapid growth of vegetative cover.

Vegetation Maintenance

Construction plans should require control of exotic or nuisance plants within the wetland during and after construction. Details on control methods should be provided for expected nuisance species. Control of herbivory by animals may be required and should be anticipated in the construction and monitoring phases. Provisions should be made for irrigation during construction with available effluent for constructed wetlands.

Land Use

Locations of restricted areas, structures, utility lines, or other infrastructure within or adjacent to the construction area should be indicated. Special construction restrictions or contractor coordination requirements should be indicated.

Erosion and Sediment Control

Construction plans should indicate the location, quantities, and maintenance of acceptable and appropriate sediment control methods. Possible sediment barriers include staked haybales, geotextile silt-screens, sod, and plant seeding. Barriers should be placed at the construction periphery and within the wetland in such a manner as to minimize sedimentation and erosion of wetland berms or edges.

Grading Plan

A grading plan should be included with the plan set that identifies the location, elevations, and dimensions of project earthwork. The plans should include sufficient information on radii, turning points, and baseline offsets for the contractor to accurately locate and build the wetland. Plans should specify soil quality requirements, soil sources and disposal areas, and means of transporting soil. Grading specifications should indicate the allowable tolerance in wetland grade elevation. Constructed wetlands require strict adherence to wetland grade specifications.

Site Preparation

Construction plans should include removing the top 0.45 - 0.6 m of substrate from the project site and stockpiling of that material to use as cover for the site to provide a seed bank or propagule source.

Contractor Selection Criteria

Contractor selection criteria should include several minimum requirements. Contractors should be able to demonstrate prior successful wetland construction experience. Contractor staff should include a person with background in wetland creation/restoration design with practical wetland construction experience. The contractor or contractor's insurer should be able to secure a performance bond equal to the cost of construction, planting, and a period of maintenance and monitoring.

Maintenance During Construction

Nuisance and exotic plants should be controlled during wetland grading and planting. Trash and litter should be prevented from accumulating in the wetland. Wetland vegetation should be irrigated or kept watered as needed during the first year initial dry season if not inundated to design depths. Water control structures and culverts should be kept free of debris and soil, and repaired if broken.

"Time Zero" Report and Final Record Drawings

"As-recorded" drawings should be prepared and certified by the earthwork contractor or general contractor prior to installation of planting materials, and submitted for approval and acceptance by the project engineer. Final "as-recorded" drawings should be prepared at the conclusion of construction that verify design elevations, water depths, and elevations and extent of planting zones. These should be submitted with a "Time Zero" Report at the completion of the project, which would include descriptions of the major wetland plant communities, densities, species and photographs taken at a sufficient number of stations to adequately cover the project (Erwin, 1991).

Original mylar or other media should be annotated and prints certified by a licensed surveyor. Variations from design, and their rationale, should be noted on the plans.

Post-Construction Monitoring

Construction and permitting documents should include a detailed description of the post-construction monitoring required to measure and evaluate whether a wetland has attained its intended goals. Sampling methods, frequency, and monitoring station locations should be described in sufficient detail to permit monitoring to be conducted by qualified individuals unfamiliar with the project. Monitoring plans should include descriptions of methods and goals of collecting data on water levels and plant species cover and diversity. Photographs of the wetlands should be taken at fixed locations as part of the post-construction monitoring process.

Monitoring Options

Additional data that may be collected will depend upon the goal of wetland construction. Periodic biological surveys of vertebrate and invertebrate communities may be performed to document wildlife habitat and ecological productivity in the wetland. Water quality sampling may be performed to document pollutant assimilation, organic matter production and export, and sediment retention. Flood retention and groundwater recharge functions may be documented by installation of monitoring wells, and water stage and rainfall recorders. Specialized input from biologists, hydrologists, hydrogeologists and engineers should be sought before designing and implementing any monitoring.

Performance Criteria

Wetland performance after construction should be determined by comparison of measured wetland conditions at selected time intervals against specific criteria. Criteria to be measured should reflect project goals. For example, specific criteria for a treatment wetland might include target effluent concentrations and expected pollutant removal efficiency, as well as other indications of wetland condition, such as percent cover by planted and volunteer plant species.

Wetland Maintenance

Corrective action should be taken if monitoring indicates that performance criteria are not being met, or if other indications are found that the wetland is not functioning as designed. Constructed wetlands performance can be adversely affected by inundation less than or greater than required by design. Flow, residence time, pollutant removal efficiency, and compliance with wetland discharge standards may be adversely affected. Wetland vegetation may be adversely effected. Possible solutions may include changing the volume, quality or timing of water deliveries to the wetland, the invert elevations of water control structures, the wetland grade elevation, and the species of vegetation to be planted.

References

Erwin, K.L. An Evaluation of Wetland Mitigation in the South Florida Water Management District. Volume I. Contract No. C89-0082-A1. 1991.

Kadlec, R.H. and R.L. Knight. Treatment Wetlands. Lewis Publishers Co. 1996.

Schueler, T.R. Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region. Metropolitan Washington Council of Governments. Washington, D.C. 1992.

Water Pollution Control Federation. Wetland Systems. Chapter 9 In Natural Systems for Wastewater Treatment MOP FD-16. Alexandria, VA. 1990.

Appendix K

Questions and Concerns That Have Been Raised About Wetlands

K. Questions and Concerns That Have Been Raised About Wetlands

Over the years, numerous questions and concerns have surfaced with respect to the long-term effects of wetlands on wildlife and on local residents whose homes are located close to a wetland site. Some of those questions and the response to each by the wetland engineers are presented in the following table.

QUESTIONS AND CONCERNS THAT HAVE BEEN RAISED ABOUT WETLANDS

Questions/Concerns Expressed by Regulators and the General Public	Response by the Wetland Engineers
Will it generate odours?	It has been found that if the wetland has been designed correctly, odours should not occur. The experience of wetland experts who have visited wetland sites around the world indicate that odour generation in constructed or natural wetlands has not occurred.
What about mosquitos?	Even though the wetland provides a greater water surface area for mosquitos to breed, this potential has effectively been kept in check at many wetland sites in several ways. The most effective is the use of mosquito fish that eat the mosquito larvae before they reach the adult stage. Nesting boxes can be set up for purple martins and swallows that consume adult mosquitos as they emerge from the wetland. Maintaining the design water level will reduce the formation of stagnant, mosquito hatching sites.
Do we know enough about this technology?	Wetlands have been intentionally incorporated into wastewater and stormwater treatment systems for more than 25 years. Volumes of literature have been written on the subject based on experience gained from hundreds of pilot- and full-scale treatment wetland systems around the world. Although more knowledge is still being gained and more data needs to be collected and analyzed, there exists sufficient design criteria to properly engineer a treatment wetland system.
Will it work in winter?	The functions of a wastewater or stormwater treatment system that rely fully or in part on physical and/or chemical processes (settling or adsorption) are unaffected by the water temperature. This would include parameters such as biochemical oxygen demand (BOD_5), total suspended solids (TSS), and total phosphorous (TP) removal. However, the treatment functions, such as ammonia nitrogen (NH_4-N) and nitrate and nitite nitrogen (NO_3+NO_2-N), that rely on microorganisms for contaminant reduction are affected by temperature and this must be factored into the design of the wetland system.
Will it work in the far north?	The application of wetlands in cold climates has successfully met effluent criteria across Canada as far north as the Yukon and the Northwest Territories.
Will it work for all nutrient and chemical types?	Wetlands have been used to effectively treat a wide range of municipal and industrial effluents. Each waste stream requires careful, individual consideration. Concentrations and types of chemicals that have not been tested in a biological wastewater treatment system should be approached with the same caution that would be exercised when determining the most appropriate conventional wastewater treatment system for a given wastewater.
Will this technology be applicable to	There are many potential wetland applications. However, experience

QUESTIONS AND CONCERNS THAT HAVE BEEN RAISED ABOUT WETLANDS

Questions/Concerns Expressed by Regulators and the General Public	Response by the Wetland Engineers
all situations?	has shown that after carrying out an initial investigation, only about 50% of the potential sites would be considered feasible for the treatment wetland technology.
Has this technology been applied to a large-scale installation?	In Canada, at Frank Lake, Alberta, a 1246 ha system has been installed to treat municipal and industrial tertiary treated effluent.
How long will it continue to remove the contaminants?	Although the oldest known treatment wetlands currently in operation have only been monitored for a few decades, experience indicates that that the life expectancy will be related to the type and strength of effluent being treated. Specific wetlands treating low strength municipal wastewater have been estimated to have a life expectancy of centuries if properly maintained. However, the removal capacity of high strength industrial systems may be less, possibly in a decade.
Will the accumulated contaminants wash out of a treatment wetland system during rainstorms?	If the wetland is designed properly, the sediment should remain in the wetland depending on the storm intensity that it was designed for appropriate wetland design includes trapping and retaining sediments in the wetland.
What about metals accumulation in the soil and plants?	Studies have shown that the accumulation of metals in the soil and plants can be quite variable. Some sites with no contaminated water flow showed levels of metals in the plants that were greater than those in a contaminated water stream. Investigations continue to determine the impact of metals accumulation on the surrounding environment.
Will the wildlife be adversely affected by the accumulated contaminants?	Based upon the scientific knowledge gained to date, the risk to wildlife is likely remote. Where bioaccumulation or wildlife exposure has the potential to become a problem, measures can be incorporated into the project design to minimize these risks. Research is continuing on this subject.